DWELLERS OF THE SEA AND SHORE

William Crowder

THE YOUNG PEOPLE'S SHELF OF SCIENCE

Edited by E. E. SLOSSON

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Director of Science Service, Washington

EVERYDAY MYSTERIES

By Charles Greeley Abbot, D.Sc.

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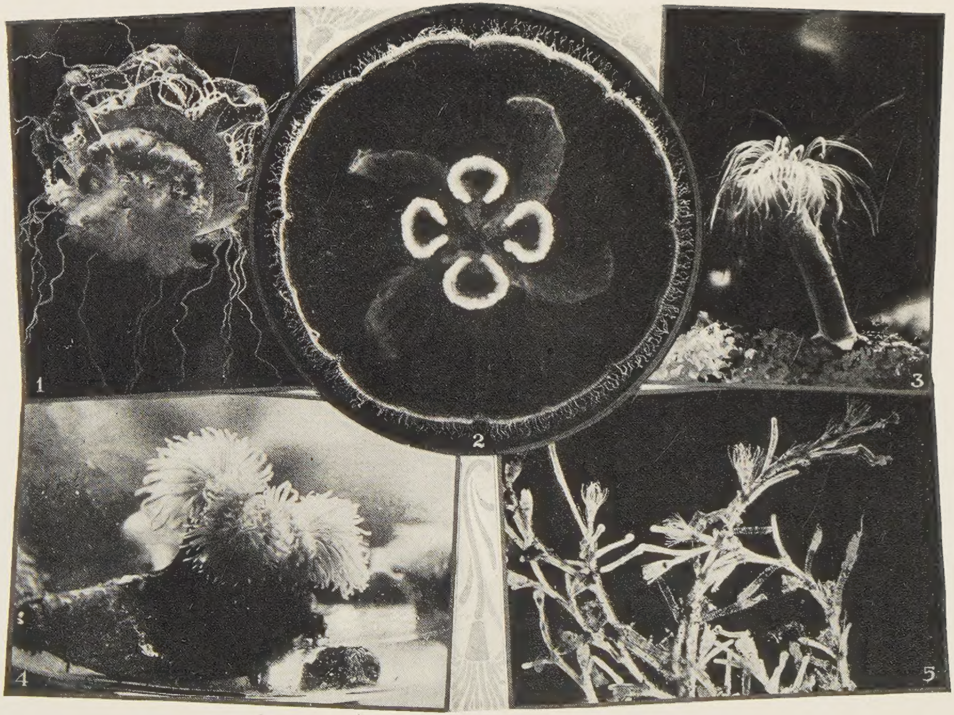

COELENTERATES. (*Frontispiece*)

1. Cyanea; a jellyfish.
2. Aurelia; a jellyfish.
3. Sagartia; a sea anemone.
4. Metridium; a sea anemone.
5. Bougainvillea; a hydroid.

DWELLERS OF THE SEA AND SHORE

BY

WILLIAM CROWDER

DRAWINGS AND PHOTOGRAPHS
BY THE AUTHOR

"Along the shore of the sounding sea."
HOMER.

"In gulfs enchanted, where the siren sings,
And coral reefs lie bare,
Where the cold sea-maids rise to sun their
streaming hair."
O. W. HOLMES

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TO

MY WIFE

INTRODUCTION

The great naturalist Agassiz used to say that a student did not know his subject until he could present it successfully in four different forms: first as a technical monograph, second as a scientific lecture, third as a popular lecture, and fourth as a simple child's tale. Probably the scientific men of our day would flinch or flunk the fourth of these tests. Yet it is possible to put the fundamental fact of any science into a form to be comprehended by the juvenile mind if one knows the knack and takes the trouble to make things plain and interesting.

And nothing is better worth while, for when the attention of a boy or girl is once directed toward the wonders of nature, and when once he gets the habit of looking for the meaning of what he sees, he has gained an aptitude of mind that will last through life and bring continuously new ideas and inspiration.

The new views of science that sometimes seem difficult and disconcerting to us elders who have been brought up on the old-fashioned theories, are often clearer and simpler than the old when they are presented directly to the fresh and unbiased minds of the younger generation. The modern gasoline motor is easier to understand than the older steam engine, and it is simpler to think of the electric current as a stream of electrons flowing through a wire as water flows

through a pipe than to think of it as a transmitted strain in a hypothetical ether. See how readily the youngsters take to the mechanics of the automobile and the workings of the radio.

It is the aim of the Young People's Shelf of Science to present modern views of the several sciences in a comprehensive and attractive form. These books are intended to be read rather than to be studied. They are not designed to be tasks, but recreations. They do not follow the conventional classification of the college, but treat of natural and industrial processes from a novel and practical viewpoint. They show that science is not a remote and recondite study but a part of everyday life, the unseen foundation of all we see and do.

EDWIN E. SLOSSON.

WASHINGTON, D. C.,
July, 1923.

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Chapter I

THE SEASHORE NATURALIST

An ancient glacier in its northward retreat over our continent left in the vicinity of Glen Cove a legacy in the form of great masses of stone, gravel, and sand. Centuries of wind and rain have done much to change the general appearance of the original deposits, and they are now resolved into green-clad hills and marshy coves. Owing to the loose character of the soil, the rains have washed out valleys of considerable size, and where these depressions adjoin the waters of Long Island Sound they compose the harbors and coves that give these shores their characteristic aspect.

But the wind and the rain have not been the only forces to determine the appearance of this region; the sea also has been a mighty factor. Many massive headlands have been slowly crumbling away under the incessant pounding of the waves. And even to-day, the comparatively quiet waters of Hempstead Harbor can be seen insidiously trying to level the land of the surrounding shore.

Near the mouth of the cove rises a high prominence. The gentle ebb and flow of the tides have laid it open so deeply that it cannot much longer sustain itself in the struggle against the sea; but with the débris thus removed, the waters are building a barrier across the

cove; so, while the land is being destroyed in one place, it is being formed anew in another. To a greater or lesser extent similar changes are constantly taking place in the shore lines of every seacoast in the world. If we were to travel along either of our long coasts, we should find that the sea seems to be wearing the hills away more effectively in some places than it does in others. This is due to several causes, chief of which are the shape of the shore and exposure to the waves. But the work of destruction is always going on; likewise, the work of replacement. In some regions, in fact, the land is being replaced at a rate for which there is not at present any explanation. Many of those great stretches of wide, sandy shores bounded by "dunes" are cases in point. Where all the material came from for those vast quantities of sand, and which is ever increasing, is one of the ocean's mysteries.

If we take up a pinch of sand from any beach and examine it under a strong glass, it will be found that the separate grains are not worn smooth and round, as we might have expected, but that they retain to some extent their original sharp, angular appearance. This is because the grains, as they are washed about, lie with their faces toward one another with a film of water between them. The film acts as a protection, preventing them from actually coming into contact and so grinding off each other's angles. Now desert or wind-blown sand grains show a quite different character. Their unprotected edges are rounded, and many of them are worn so small that they are in reality nothing more than fine particles of dust.

Where new land is forming on a coast, the shore

generally has an upward slope, and the low tide leaves a wide expanse exposed to the action of the sun and winds. As the sun-dried sand begins to drift here and there, some of it is carried up the shore landward and remains. These accumulations gradually grow larger and become compacted by the rains; and eventually plants take root in them, further binding the sand together. Such newly made land is extremely marshy, and in certain areas vast tracts of it exist close to the sea. At every high tide, the water floods these marshes, but eventually their channels become choked up with the gathering sands and the sea no longer covers them. They are soon filled with vegetation, and their level is raised and drained; in this way a swampy waste inhabited only by fiddler crabs and snails becomes in time, perhaps, the site of a thriving village. Thus, the sea gives as it takes.

On rocky coasts at the base of the cliffs will generally be found rocks which have fallen from above. They are of all sizes, some of them weighing many tons. These for the most part have been dislodged from the parts of the cliff which are out of reach of the ordinary action of the waves; in this case the agency for their downfall has been the rain or frost or both. Rain, in its descent from the clouds, absorbs certain gases from the air which, when combined with water, have a dissolving chemical action on the rock. In time this causes the face of the cliff to become pitted and cracked, often loosening considerable masses of material. In latitudes of frosts this weathering process is hastened by the freezing of the water that fills the cracks. The conversion of the water into ice is accompanied by an

expansion, and this acts as a wedge forcibly splitting the rock apart. The fractured rock may not at once fall, being held in its place by the binding action of the solid ice, but when a thaw comes the weakened material gives way and is precipitated to the beach with a mighty roar. Here the waves take up the work of further disintegration; at every storm the rocks are rolled around and jostled against each other until they are broken into smaller fragments and ground down into pebbles and sand.

No other region offers so pleasing a variety of picturesque scenes as does the seashore. On the one side is the colorful water, incessantly in motion, ever-changing in its aspect; on the other, the rugged cliffs or maybe quiet coves or bays fringed with a beach of glistening sand and backed by hills and fields bedecked with verdure. The frequent changes in the character of the land further increase the variety of these scenes. Where it is composed of soft or loose material we find the coast line transformed into graceful curves, and the beach is an unbroken stretch of very fine sand; but where rocky cliffs exist, the aspect is often wild, and the shore is strewn with stones and bowlders of every size. And with what delight do we watch the incoming waves as they roll over the sand and pebbles or wash around the rocks!

The picturesque in nature is attractive even to the most passive observer, and many who see no beauty in small things are constrained to pause with admiration in the presence of natural spectacles. But the true lover of nature will find many other attractions than scenic beauty to allure him to the shore. He loves to

read the history of the sands and rocks, to observe in what way the general scenery of the coast is determined by the character of the land, and to discover from the beach what has been the action of the waves in shaping the contours of the cliffs. He finds a unique pleasure in observing which plants are peculiar to the

A PROMISING SPOT FOR THE NATURALIST.

shore, and how they differ from the flowering forms away from the sea. He also finds a delight in watching the sea birds, the insects, and other lower forms of life, and in learning how these various creatures are distinguished by structure and habits from those of inland regions.

Nor is he ever at a loss for opportunities to follow

his favorite pursuits. Regardless of whether the tide be high or low, or whether his locality is one of sand or rocks, or even mud, an endless variety of forms await his inquiring notice.

To the beginner—and to the experienced naturalist, too—the character of the shore is important, as it indicates to a large extent the types of plants and animals which are most likely to prevail. A sandy shore, although appearing quite barren and uninteresting to the ordinary observer, nevertheless teems with life. But its inhabitants live mostly under the surface where their presence often can be detected by the openings to their burrows. Some of the burrowers, such as certain clams, betray themselves by sending conspicuous jets of water into the air. However, the greater part of the underground population gives no visible sign of existence; and to one who was unaware of the fact, it would seem incredible that a turn of the spade will reveal a numerous crowd, among which will ofttimes be found some of the most beautiful creatures in the animal kingdom. Snails, crustaceans, and worms are extremely abundant over the entire beach, and careful scrutiny of drifted sea wrack will detect a host of other forms. In the water, of course, the evidence of life is more obvious. When the tide comes creeping upward, a numerous group begins to assemble. Almost at the very edge of the water, nosing their way here and there, can be seen the minnows. Some of the tribe peculiar to our eastern coast will show a delightful familiarity by nibbling harmlessly at the wader's toes or ankles. These are the Mummichogs; and in brackish-water regions they outnumber all other shore fishes.

In a manner of speaking, many of the fishes may be quite visible but yet unseen. This is because of their shape or coloring, which makes them inconspicuous against the bottom. Unless one had an unusually keen eye for such things, it would be difficult to distinguish some forms from inanimate objects. The slender pipefish, for instance, resembles the stemlike fragments of vegetation washed back and forth by tidal currents. Visible forms are plentiful, nevertheless; among these are the sea robin, that strange fish which crawls as well as swims; the skate, an innocuous cousin of the shark, and the shining silverside. Then perhaps on rarer occasions one may obtain a glimpse of that quaintest of creatures, Hippocampus, the little sea horse. Crustaceans, too, are common. Hermit crabs can be seen carrying on their interminable brawls, sand crabs are present, half buried and awaiting their prey, while shoals of shrimps frequently go flashing by.

As I have hinted, muddy shores are not without their interest. These are usually associated with marshy regions of brackish water or with shallow bays and estuaries. Burrowing in the muddy banks will be found the fiddler crab, a grotesque creature with a claw almost as large as the rest of his body. In the groves of eelgrass, which are submerged at every tide, many small animals are living which are seldom seen elsewhere. The eelgrass is a flowering plant and is one of the very few which will grow in salt water. Among the animals which crawl over its bladelike leaves is a little snail which attaches its egg cases to the plant, and these look so like the seeds that are formed in the grooves of the leaves that they cannot

easily be told apart. Other creatures have a body resemblance to the shape and color of the leaves. At the roots, in the mud, other small animals are abundant. The pools and channels of mud flats contain numerous varieties of mud crabs; if one is discerning he will often be able to find in such places sluggish types like the spider crab, which hides under decaying weeds or covers itself with vegetation, and the mud

COLONY OF BARNACLES LIVING ON A ROCK.

crab, with a load of silt and débris tangled with the bristles on its back. Beauty is also present. Attached to the submerged plants are silky sprays of the wonderful hydroids, but a good glass is required to reveal the delicate and exquisite structure of their plantlike bodies. Indeed, there is no end to the charming revelations one can make with a glass, and this holds equally true for the waters of every character of shore.

Rocky shores with their clefts and crannies and

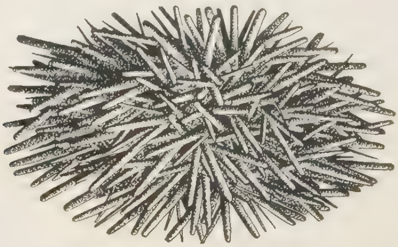
numerous pools also have an interest all their own. The seaweeds which grow in great abundance and variety harbor in their fronds many animal forms which do not occur in localities of sand or mud. In the struggle for existence among both the plants and the animals which inhabit the shores every possible advantage is sought by the individuals. This is particularly plain among the rocks. Every bowlder bears on its seaward side a colony of barnacles, and vigorously disputing the space these creatures occupy are

CAPRELLA, A SMALL SHORE CRUSTACEAN.

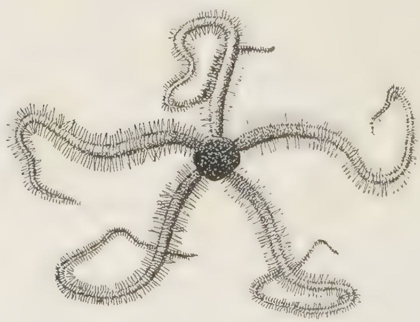
mussels and other stationary mollusks. Even the seaweeds contest the right of the barnacles to dominate; they grow so thickly in some places that the latter are often crowded out. These rockweeds in turn support a curious population. Crawling over the leathery fronds or firmly fixed thereon are sea spiders, moss animals, snaillike worms which secrete spiral shells, and in sundry places may be seen attached by its hind legs, swaying its lengthened body to and fro, that oddest of crustaceans, little Caprella. Among the other creatures to be found on the fronds are certain snails, which simulate the color of the plant, or are striped to make closer their resemblance.

When the tide is out there will be found secreted under ledges and in sheltered places starfishes and sea

urchins and different sorts of crustaceans who are active only when submerged. But the less exposed nooks shelter permanent residents as well. In these



STRONGYLOCENTROTUS; A SEA URCHIN.



OPHIOCOMA; A BRITTLE STAR.

places live many delicate seaweeds which are unable to endure the force of the waves or the withering action of the sun; animals, too, no less inclined to brave the open, thrive in these little solitudes in considerable numbers. Below the low-tide mark, pink, orange, or scarlet incrustations of small sponges may be seen like

luminous patches of color in the gloom of miniature grottoes; while partly masked by the long pale-green threads of vegetation are numerous creatures in hiding; some are waiting to pounce upon their prey and others are seeking seclusion from their enemies.

The numerous pools that occur on every type of

A WHELK'S SHELL COVERED WITH SEAWEEDS, HYDROIDS AND TUBE-BUILDING WORMS. FOUND IN A TIDE POOL.

shore afford a refuge for some species of plants and animals which ordinarily are found only below the tide marks. In the clear, peaceful waters are usually contained the corallines, tufts of pretty pink and white seaweeds which look like miniature branches of coral, and the brittle stars, slender, active starfishes which climb about the sea plants, and the attractive sea anemones, variously colored creatures of prey which resemble

flowers. On the pebbles or sand that forms the floor of the pool itself, may appear the transparent, phantomlike prawn, gently waving its long filamentous feelers, then darting suddenly backward so swiftly that the eye cannot follow the movement; or, it may be, that a chance view may be caught of the scallop, that ornamental clamlike creature which swims by snapping together the valves of its shell.

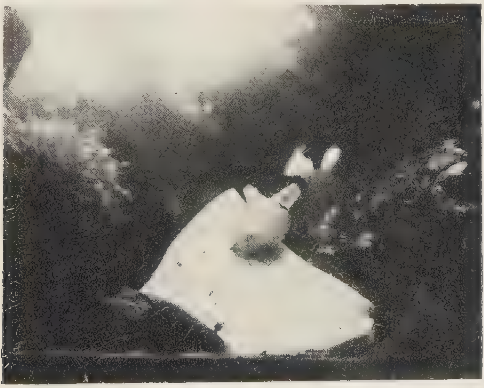
It so happens that on the piles of wharves many kinds of sea creatures will find a lodging place. Some

PENTACA; A SEA CUCUMBER.

of these are attached forms such as hydroids, anemones, moss animals, and sea squirts; others, like the shipworm and the gribble, are boring animals, and are therefore less conspicuous.

Thus, there is much to find and admire among the living forms which inhabit the seashore. It is perhaps the most interesting of all the haunts of life. Although certain types may occur invariably in those regions that favor their development, life on the whole may in dif-

ferent localities be surprisingly varied and even in one place be very diverse. In fact, it changes from week to week. Repeated visits throughout the year seldom fail to mark the presence of numerous hitherto absent forms. The finding of these forms, the discovery of their marvelous beauties, the learning of their ways, afford the lover of lower living things many delightful and fascinating hours.



SEA SQUIRT; ATTACHED TO A FRAGMENT OF A CLAM SHELL. (PHOTOGRAPH TAKEN IN THE WATER.)

Harbor Beach and its environs is one of those regions that in a degree comprise within a small compass the several kinds of shore formation and the various inhabitants which have just been reviewed.

Here, the sheltered cove, the salty meadows, the bowlders, the sandy reach, the nodding shore plants and flights of sea birds represent to the stranger nothing more, perhaps, than a quiet place in a peaceful country; yet it is the realm of great mysteries, the

scene of thrilling adventures, the gateway to a strange world.

We all like to adventure. And who does not love a mystery? It whets our curiosity and adds zest to our lives. Surely, this would be a dull life if there was nothing to learn, nothing to excite our imagination or our wonder. Therefore, to resolve some of these mysteries, to recount an occasional adventure, and to follow a few of the paths leading throughout this amazing realm, shall be the purpose of the ensuing chapters.

Chapter II

SOCIAL LIFE IN THE SALT-WATER WORLD

Who has ever visited the seashore during a storm without a feeling of great awe as the thundering waves broke against the rocks or hurled themselves with their foaming crests high upon the beach? With each succeeding surge of the mighty masses of water the impact causes the very earth to tremble. If one is of a reflective nature, those truly are tremendous moments. It is then that one is impressed with the significance of the warfare which is being waged by the sea upon the land.

Although one can well understand how the most obdurate of coasts sooner or later must give way to the incessant pounding, how is it that the continents of the world have so long sustained themselves in the strife? Does it not seem that ultimately dry land would completely disappear?

Well, it is true that shore lines are breaking down. Indeed, it is quite certain that considerable bodies of land have dwindled away for this very reason. But it is equally true that notwithstanding the frittering away of its coasts a continent occasionally actually increases in size.

This apparent paradox is easily explained. The earth, as we all know, was once very hot; it is at

present a cooling mass. Now a cooling body contracts, and as it does so it has a tendency to warp. Particularly does this become evident in the case of our globe. Although its rock-ribbed surface is seemingly solid, nevertheless, it is endowed with great plasticity, and consequently the shrinking shell results in rumpled ridges and rugosities. Time and the elements have done much in the past to obliterate these folds and wrinkles, but they are still manifest in what is left of the mountain ranges and in the abyssal valleys of the sea.

In many regions in the world the contracting crust is causing certain portions of continents slowly to rise while at the same time, but in another place, it is causing the land to lower. In the latter event the sea hastens the disappearance. Where an elevation is taking place, however, it sometimes progresses more rapidly than the waves can work. Notwithstanding, to some extent the sea is always cutting away our shores.

There is enough water in the sea easily to cover the entire earth, provided the earth were a perfectly smooth sphere—that is, if all the mountains and valleys of the land and sea were brought to a common level. But that the earth was ever completely inundated at one time seems unlikely, for it appears that the more solid part has always been too unstable. Now a portion is up, then it is down. This seesawing, this oscillating of the land, has continued throughout so many ages and in so many places that to-day there is no continent or part of a continent which has not at some time been at the bottom of the ocean. What is more, it is

very probable that some parts of the ocean floor form the site of what in some previous age were wind-swept peaks or sun-kissed plains. Of our continents, then, the ocean is, in truth, at once the cradle and the grave.

It is plain that the mobility of the sea is no inconsiderable factor in shaping the destiny of the land. This mobility, however, is manifested in another way, and in one which is very vitally concerned with the destiny of all life peculiar to the seashore. I here refer to the phenomenon of the tides.

Most of us know vaguely, perhaps, that the tides are in some way influenced by the moon. This, in fact, becomes evident to the most casual observer. For the slightest acquaintance with the seashore soon reveals the singularity that at the periods of new moon and full moon occur the greatest variations in the rise and fall of the water. In other words, at the time of these two phases of the moon, which is to say, every fortnight, the tides reach their highest point during the flood and their lowest mark at the ebb. Thenceforward until two weeks later, when the moon is in the quarter phase, the variations daily grow less; after this they gradually increase again until the time of new or full moon. Now, if one is more than ordinarily observant he will have noticed further that the time of high tide at any selected spot is always the same for any given period of the cycle of the moon.

It will be inferred, therefore, that the tides move in some mysterious manner in response to the attraction of a magnetic moon. But here is a curious thing. We know that the sun has a far greater attractive influence

on the earth and its oceans than has the moon. What is it, then, that gives the latter its apparent precedence over the sun in the regulation of the tides?

To conceive this clearly, we must take into account the relative distances of these two bodies from the earth. Our globe is about eight thousand miles in diameter. Yet this is a very small fraction of the distance to the sun which, roughly speaking, is ninety-three million miles away. Consequently the pull on the earth is about the same throughout its entire mass; or, to put it another way, the attraction for that side of the earth nearest the sun is but slightly more than for the side more remote. A quite different aspect presents itself, however, when we consider the moon. The distance of our satellite from the earth being only a quarter of a million miles, it will be seen that the diameter of the earth at once becomes a very considerable fraction. The result is that the side of the earth facing the moon is subjected to a much stronger pull than the opposite side. Now the waters of the ocean respond more readily to the attraction of the moon than does the hard crust of the earth, and as a consequence they are caused to bulge out on that side nearest the moon. Again, since the attractive force of the moon is weakest of all at the opposite side, and since the waters on that side are attracted less than the solid earth—the latter being pulled away, so to speak—they bulge outward on the side away from the moon also.

From this it will be seen that we get a condition wherein two high tides are produced simultaneously on opposite sides of the earth. It must be borne in mind, however, that the earth is continually turning on

its axis, a complete rotation occurring every twenty-four hours; and as the tides necessarily follow the moon which in itself revolves around the earth approximately every twenty-eight days the changes in the tides occupy on the average six hours and a quarter each; thus making high and low tides occur about an hour later every day.

Now in all strictness the influence of the sun is not so negligible a factor as it may appear from the foregoing. Although its attraction is considerably less than that of the moon, it is still an attraction. This we find is evident in the fortnightly fluctuations of the tides. As was pointed out, extreme high and low tides are at the time of the new and the full moon, whereas the least variation is during the quarter phases. The former are known as "spring tides"; the latter as "neap tides." As we follow the moon in its various phases, we find in starting with the new moon that it is nearly on a straight line—sometimes exactly so—between the earth and the sun; therefore, the attraction of the sun added to that of the moon, assists the latter, as it were, in its pull, thus causing a spring tide. About a week later when the moon is in its first quarter it is in a position at right angles from the sun as viewed from the earth. The tides are now more modified, for the moon no longer has the help of the sun. The truth is, each of these bodies is trying to produce a tide all its own, the moon on one meridian and the sun on another, but a quarter of the way around the earth; the consequence is that though the moon's pull is stronger its efforts are minimized by the sun's power in holding the water in check. A neap tide is the result.

In another week we find the moon full and in a line opposite from the earth to the sun. Although pulling in opposite directions they produce a harmonious result. For as two tides are formed at the same time, one on each side of the earth, it follows that the influence which is one body's loss is the other's gain. The following, or third, week we see the moon in its last quarter; it has by then completed three-fourths of its cycle. Once again the moon is at right angles from the sun; once again the tides are at their slightest range; from this time onward they will increase daily until the moon is full, the cycle then continuing as before.

If the earth were entirely covered with water, the tidal swell would travel in a westerly direction and keep its place regularly on the meridian of the moon; but we know that actually the movements of the waves are exceedingly complex. Observations along different points of our seaboard show that there is sometimes a great difference in the time of high tide between two or more places situated close together. For example, high water does not occur in Hempstead Harbor until more than three hours after the time of high tide at Governor's Island in New York Harbor, less than thirty miles to the west. Now this lagging of the tides is noticeable to a great extent on all continental shores, and it is due partly to the retarding action of the latter, partly to the inertia of the water itself, but mainly to the irregular distribution of the land which breaks up the tidal wave into innumerable wave crests, vastly restraining their progress.

Let us note one more singularity. This is the difference in range, or vertical movements of the tide, in

different parts of the world. It is well known that the differences between the tide levels of continental seas are greater than those to be observed on the shores of oceanic islands. Now this is also due to the irregular distribution of the land which has a tendency to deflect the wave crests, causing them to pile higher than they would do in the open sea. But it so happens that differences occur on the same coast line. High tides are especially noticeable where they break into gradually narrowing estuaries and other channels; the incoming water, being compressed laterally, is consequently increased in height. Thus, in Hempstead Harbor, which receives the retarded waters of the Sound, the mean variation of the tides is about six feet, but in the Bay of Fundy where the incoming tide piles up with great force, it is said the water reaches the extreme height of ninety feet.

Now, I have gone into this matter of the tides at some length not alone because of its interest to those making their first acquaintance with the sea, but also in order better to visualize for the reader the fundamental nature of an element that has largely to do with the interpretations we shall make of the strange habits prevailing among many dwellers of the shore.

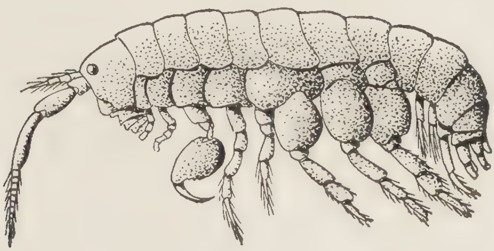
Undoubtedly, the greatest attraction of the seashore for the collector and naturalist is at the time of the ebbing of a spring tide. As the retreating waters lay bare the land, a promiscuous multitude makes its appearance. From all directions come creatures of every description. Through the air, from out of the earth, and over the land they arrive: birds, insects, and crustaceans. Mollusks, too, and worms and

beasts with spines claim our attention as the tide leaves these animals high and dry or stranded in some shallow pool. The tidal zone is peculiar in that, while its upper limit marks the frontier between two worlds whose denizens are totally unlike in habits, the region between this and the lowest limit of the spring tides is one that

SEAWEED DEBRIS LEFT AT THE TIDE MARKS.

has an alternating condition which makes it periodically favorable to land or marine animals. In brief, the tidal area is a sort of "no man's land" alternately occupied by the animals of the land and those of the sea. It so happens, though, that some can hold their ground under either condition, whether this be marine or terrestrial.

As the tide turns from high to low it leaves one unmistakable mark to indicate its highest level. This is in the form of a long line of wilting seaweed and organic débris. Of this low-lying heap, by far the greater portion consists of the common green seaweed, Ulva, or sea lettuce, as it is popularly called. The sea lettuce, having become detached from its anchorage on the bottom, is carried ashore by wave action. Clumps of olivegreen and brown seaweeds sometimes are in the mass, and often one will find those rarer and more



ORCHESTIA; THE SAND FLEA.

delicate forms, the brilliant red plants of the deeper waters. Particularly are the latter in evidence after a period of stormy weather. Often, too, a sponge is torn from the outlying bottom and drifts about, finding its way at last to the tangled tide mark on the shore.

As far as one can see, this telltale line extends itself along the beach. At first sight it would appear that the moist mass is destined shortly to become a heap of rotting refuse. It is not, however, so destined. Barely does it become stranded by the tide when it is beset by a swarming population. Flies, beetles, and other insects are engaged in its reduction. But the most active

and efficient agent is one that is properly from the seashore itself. This is the sand flea, Orchestia. This busy little scavenger is the purifier of our shores. Without him our beaches would tend to become places to be avoided rather than regions of charm. His number is legion; yet he works virtually unseen. If, however, we turn over the débris about us we will find a surprise; the ground underneath becomes alive with him. Our intrusion on his privacy, however, causes a multitudinous dispersal, for he immediately scampers away in hundreds and buries himself in the sand or finds some other hiding place.

No sooner does the receding tide expose a portion of the beach than it takes on an animated aspect. From a thatch-covered mud bank near at hand, fiddler crabs emerge in droves. Like herds of grazing cattle, they follow the creeping water and search among the stones and pebbles for the minute plant food on which they live. The males are easily distinguished by the enormous claw each individual carries. No other crab but the fiddler is provided with a pincer of such prodigious proportions.

A bird alights on the shore, and a panic ensues. Pell-mell the fiddler crabs rush toward the thatch grass and plunge indiscriminately into the burrows which honeycomb the bank. Fear inspires them to make no choice. It is every crab for itself. In the alarm each dives sidewise into the most convenient retreat, and it sometimes happens that a single burrow is completely filled with the fugitives.

We recognize the newcomer as the green heron; it is hunting for a meal. It settles down on the sand and

stands motionless near the edge of the water. The fiddler crabs, in common with the majority of wild creatures, recognize only moving objects, and it is not long before they once more emerge from their hiding places and wander toward the water.

But see what is happening around the bird. Rising out of the smooth sand other fiddler crabs can be seen stealthily and warily making their appearance. Unless you are in the secret you would think that these are members of the mud-bank colony which had, of necessity, taken refuge in the sand. But they are, in fact, entirely different individuals. This region abounds with two species of fiddler crabs whose habits are completely dissimilar. One (*Uca pugilator*), that which first engaged our attention, lives only in the muddy soil peculiar to the thatch-grass meadows. It is of a dark slaty gray—somewhat like the soil in which it lives—except in the case of the male whose great claw, ofttimes much larger than the rest of the body, is of a bright yellow hue. The other species (*Uca minax*) makes its home in the sand, where each crab occupies a burrow of only a few inches in depth. This fiddler crab is nearly alike in shape with the mud dweller. But in color, as well as in its general habits, it is far more attractive than its brethren of the muddy banks. However, as a later chapter will be devoted to this interesting animal, we need not further consider it here. Let it suffice by saying that it is this species which we find making its appearance near the motionless heron.

Suddenly the bird plunges its long beak into the water, pulls out a coiling sandworm, and with a short

run takes the air with lazily flapping wings. Another panic; another rout in which all fiddlers of both species take part; then, once more, not a crab is in sight. Plainly, the fiddler crab is a shy creature. Notwithstanding that these animals live together by the thousands, and that they are of a conspicuous size (the adults are more than two inches in breadth) their extreme timidity makes them little known to the average seaside rambler. The appearance of any stranger in the neighborhood, whether it be bird, beast, or man, is always the signal for their retreat. Still, one can make the fiddler crabs' acquaintance if he but has the patience to wait quietly near their burrows. And I may add that by so doing he will be amply rewarded for his pains.

By the time the ebbing tide is three hours old—that is to say, when it is about halfway out—numerous rocks studded with barnacles have already been left high, if not quite dry. Nearly all of these irregular-shaped bowlders have concealed in their depressions and crevices clusters of starfishes. Here and there the uneven ground has retained the water, and in these transparent pools one catches a glint of gleaming sunlight from the iridescent dead seashells strewn over the bottom. Broad bright areas of rippled scurf sand also have made an appearance, vying with the brilliance of a summer sky in their lovely whiteness.

But the beauty of inanimate nature is not the only beauty that the lowering tide reveals. Many animals adorn the glistening beach. Wherever one may search, in the tide pools, under the stones or in the sand, he is sure to encounter creatures whose sightliness is seldom

matched by the dwellers of dry land. Now, strange to say, among the most beautiful are many of the worms. Look at Nereis, the sea worm. This animal usually lives under stones and in the sand, but ofttimes frequents the tide pools in search of prey. Seen in the latter it is like a glittering chain of blue-green opals flanked with precious coral. The sides of its colorful body are lined with gills of pearly pink; from under every gill projects a sheaf of bristles reflecting the luster of pure gold. But the palm of beauty unquestionably should be awarded to Aphrodite, the sea mouse, a worm whose appearance has excited the admiration of every age. To the untrained eye it does not look like a worm; and therein, perhaps, lies the secret of its charm. This, in a way, is unfortunate. Had earlier observers known its identity, it is probable that ere now many other members of the group would have shone in popularity by reflected light; consequently, their habits would be better known. Its every motion is productive of a play of prismatic tints, but it is vain to attempt an adequate description of the ineffable nuances, the evanescent hues, that endow Aphrodite with its strange beauty. Graphic representation itself is unable to reproduce the charming colors caused by the diffraction of light on the translucent texture of its hairy covering.

It must be admitted, however, that beauty in some instances is merely a mask. It often hides an unlovely trait. What could be more enchanting than the white anemone (*Sagartia leucolena*) as it stands no taller than one's thumb, with its translucent tendrillike arms undulating in the soft currents of a tide pool? Incom-

parably gracile, it sways innocently, innocuously, the verisimilitude of an alluring spectral flower. Yet one would little suspect its lethal nature. But should a young sea worm or other small wanderer chance to glide against the ghostly petals, it is lost. For the petals are murderous tentacles; and they can inflict a

THE WHITE ANEMONE.

paralyzing shock, overwhelming the luckless victim like the surge of a hundred thousand volts.

Let us attend to the tide. When the water has reached its lowest ebb it has at the same time reached the point of its greatest productivity for the collector or observer. Yet for that matter, in the five hours and more which have elapsed during the tidal descent, enough material will have been found to satisfy the most ardent hunter. It is at low spring tide that all

manner of animals are to be found; for the tidal region between the low-water neaps and the low-water springs is inhabited by a far more numerous species than any other part of the seashore. All sorts of fishes, crustaceans, mollusks, worms, etc., will be found in hiding here waiting to be covered by the next tide. For the most part these will be found beneath the stones, in the ground, and, in the case of anemones and certain other low forms, attached to the under surfaces of the stones themselves. Living seaweeds are also in abundance, and in their wet fronds are sheltered minute creatures whose strange form and structure are to be revealed only by the microscope.

There is, furthermore, a conspicuous abundance of the larger animals of the shore. Limulus, the horseshoe crab, can be seen plowing his way through the mud. Around about the molelike creature the soft ground is pitted with innumerable holes of about the diameter of an earthworm's burrow. Geyserlike jets of water ejected from various orifices indicate the presence of the soft-shelled clam (*Mya arenarea*). Periwinkles and other snails are here, there, and everywhere crawling over the surface of the mud, leaving in their trails their familiar furrows. Cancer, too—the rock crab, so miscalled—we will see; half buried, but on the alert, it awaits with its dangerous-looking, bone-crushing forceps in readiness to pounce upon some smaller passer-by.

To enlarge upon the wealth of living forms found here would be wearisome. Yet the most casual reference would be incomplete without mention of the mussels. The extensive black beds of these mollusks

are exposed at every low spring tide. So great is the number of the individual units that they are to be estimated only in millions. Excepting, perhaps, the barnacles, they are the commonest animals in this region.

Now, although the mussels are peaceable creatures, their life is not exactly a peaceful one. Living as they do on the organic motes held in suspension in the water and on live food of microscopic dimensions, they have no need of weapons of offense; and as to defense, the two-valved shells which protect their soft bodies are inadequate to resist the attack of their enemies. And these are many. Few flesh eaters there are that do not take toll of their numbers. Incapable of locomotion—as that term is ordinarily understood—the mussels are easy prey to the starfish, sea urchin, and other slow-moving animals; and these, together with crabs, fishes, and birds, are continually engaged in their slaughter.

Indeed, it would sometimes appear that the mussels are bent upon destroying each other. They exist in such enormous numbers, layer on layer, that they frequently actually poison one another by their waste products. Many, moreover, are smothered by the accumulation of silt and other matter settling down from the upper masses.

Nevertheless, their worst foe is not themselves. Their deadliest enemy is, however, not far removed in kind. It is, in short, another mollusk. This mollusk is the moon snail, a creature which is an outstanding example of the amazing contrasts sometimes found in this strange world.

Chapter III

THE MOON SNAIL

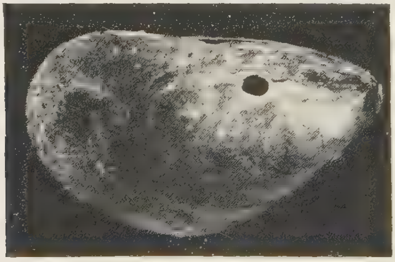
About the first thing to strike the attention of the amateur naturalist on his initial acquaintance with the sea is the countless number of dead shells that whiten the beach at various places along the shore. Cast up by the incessant action of the winds and waves, these objects of sundry shapes and sizes are imbedded in the sand and frequently are heaped in veritable windrows. Indeed, the very sand that beautifies the beach is not wholly of true sand, but to a large extent is composed of the crumbling fragments of this selfsame shell material. Everywhere in sight, littering the shore, is monumental testimony of the millions of mollusks constantly meeting their death in the adjacent waters. It is as if some giant hand had swept the sea and left the shells to bleach in the blighting light of the seasonal suns.

Often the patterns of these fragile tenements are varied and pretty. And there are some of exquisite hues. But by far the greater part of these enormous ossuaries consists of the remains of those homeliest of mollusks, the mussels.

Now few animals of the sea die directly from old age. Their existence is generally terminated by attacks

from natural enemies or other accidents. These enemies are sometimes large, sometimes small; they may be microscopic. Surprising as it may appear, after long resistance to the former, many animals reach a ripe old age only to succumb to the insidious attacks of the latter. Of course, the weaknesses due to old age make them especially liable to the invasions of these invisible hordes; nevertheless, sooner or later, the great majority of marine animals meet a premature death.

Thus it has been with the occupants of the shells on

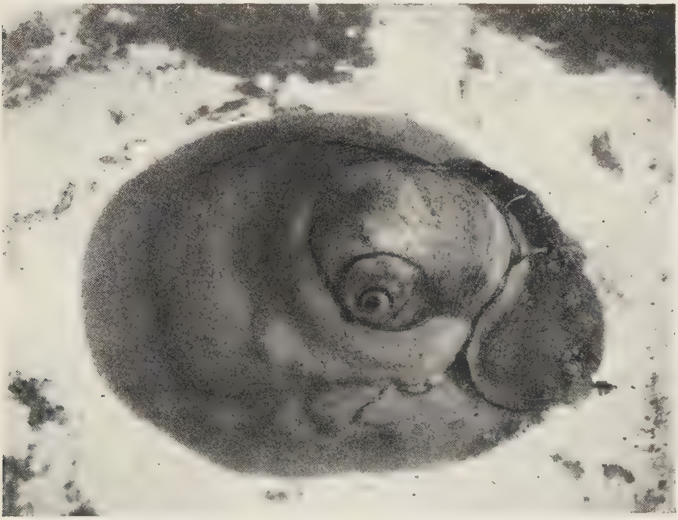


HOLE DRILLED IN THE SHELL OF A MUSSEL BY A MOON SNAIL.

the beach. In the case of the many, both the bivalves and the univalves show one unmistakable clue to the identity of the assassin who dispatched them. This is a small round perforation in the shell through which a wheat straw can be passed. It is the mark of the moon snail or one of its carnivorous brethren.

The moon snail (*Lunatia heros*) is easily the largest shell-bearing mollusk in these waters. When full grown its rounded, whitish, spirally coiled shell is about four inches long. But like the familiar pond snail, the animal crawls on a large fleshy foot. This foot with its

adhering mantle is of enormous proportions. So large, when protruded, as to envelop completely the house which was designed to shelter it. Indeed, to see this creature retract its fleshy body is to witness a very amazing feat. It is like that trick of the conjurer



MOON SNAIL. (PHOTOGRAPH TAKEN IN THE WATER.)

where he makes an almost incredible quantity of paraphernalia disappear into his cornucopia.

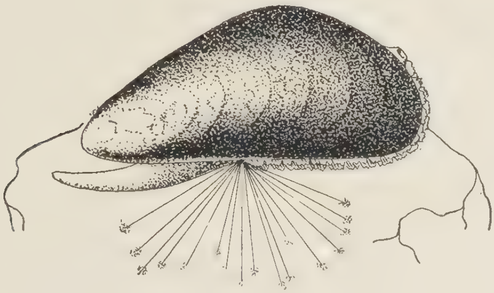
The moon snail travels in search of its food either under or over the surface of the sandy bottom. And for a snail it moves with striking rapidity. The proverbial slowness of the land snail is not reflected in the actions of its marine relative. Although in these waters it is the greatest enemy of the mussel, it is an

eater of all flesh, be this dead or alive. What is more, it will with equal readiness devour one of its own species.

MOON SNAIL WITHDRAWN IN ITS SHELL. THE DARK AREA IN THE OPENING OF THE SHELL IS THE OPERCULUM, OR "DOOR," WHICH PROTECTS THE ANIMAL FROM WITHOUT.

Curiously, this active creature is blind. Yet it is unerring in the detection of its prey. This ability to find its food, of course, is due to a sense organ, the nature of which is not hard to guess. It is an ability somewhat like that of a dog's on the scent of game;

but with this difference: the dog is guided by the sense of smell; whereas the moon snail, from the very nature of its surrounding element, is perforce restricted to the sense of taste. In short, the effluvium of its food is carried in the currents of the water, and this latter medium is tasted rather than smelled.



MUSSEL ATTACHED TO A ROCK.

In turning to the common prey of the moon snail we find that this bivalve differs as greatly in its habits as in its appearance. It is possessed of two shells, or valves, equal in shape and size. These shells are hinged, and when viewed from the side are slightly triangular, are rounded, and are about twice as long as they are wide. Sometimes they attain to a length of five or more inches, but more commonly they are three inches long. In the living animal they are dark, almost black, but exposure soon turns them to a pearl gray. Now the mussel is usually content to remain rooted to one spot the greater part of its life, which it does by attaching itself, when young, to any solid object by means of numerous tough silken threads, called byssii.

The manner of making and fixing these byssii is not greatly unlike the method of the garden spider in spinning its web. Although it has acquired a stationary habit it can shift its location when the spirit impels it. When it wishes to move, it fastens a few byssii well out in the direction it intends to travel; then, detaching those in the rear, it hauls itself forward by pulling upon the extended threads. But this is a slow, and seems to be, certainly, a laborious process; far too slow, in fact, to enable it to escape from its enemies, even though it tried.

It is hard to conceive a more monotonous existence than that led by the mussel. It would almost seem that the excitement of a violent end would come as a welcome in such an eventless life. Beyond gently opening and closing its valves, it seldom displays any activity; but even this movement has its limitations. The valves never open very wide—no more than to make a goodly sized slit in which can be seen the rich reddish brown velvety fringe of its fleshy mantle.

From this it will be readily surmised that there is nothing spectacular in the moon snail's attack on this unresisting creature. The excitement and action which mark the chase of most predatory marine animals are utterly absent here. The aggressor simply approaches its victim, folds its capacious foot and mantle around it, completely hiding it from sight, and remains immobile for the greater part of an hour. After which it releases its hold and glides away to bury itself in the sand.

Yet, notwithstanding the apparently easy manner in which the moon snail captures its food, its method is

not without interest. Nor should it be assumed that this peaceful process is devoid of effort. Although not noticeable to the eye, when this animal has wrapped its slimy mass about its prey it is actively engaged in a frightful operation.

It may as well be said at once that this mollusk is the most ruthless butcher on the floor of the sea. There are other animals which dispatch their victims in far greater numbers, but in point of refined cruelty and deadly technique the moon snail is easily the master executioner.

In separating the shells of a mussel recently released by this carnivorous creature, we find the interior soft parts to have been nearly eaten away. Nothing remains but a few shreds of the fibrous attachment that held the animal to its hinged cell. It could not have been cleaner had the shells been scraped with a scalpel. Near the hinge, on one of the valves, is the telltale perforation whose white countersunk edge, contrasting with the dark exterior, show how the moon snail had reached its victim. Now the clean-cut bevel around this hole denotes the use of an extraordinary tool. This is in truth the case. The moon snail, in common with others of its class, possesses a drilling apparatus that is unique in the animal kingdom.

The drill is contained in the proboscis, an organ ordinarily retracted within the mantle but capable of considerable extension. It is a curious implement, this drill. It is a transparent, ribbonlike band of horny texture, the surface of which is ornamented with rows of tiny teeth. The band itself is less than a thirty-second of an inch wide, and the teeth, or cusps, are not

visible without the aid of a good lens. This boring apparatus is virtually a rasp armed with hundreds of abrading points. It is located well up in the proboscis and is brought into play through the peculiar ability of this organ to turn itself partly inside out, much in the fashion that the finger of a glove can be turned within itself.

RADULA, OR RASPING ORGAN OF THE MOON SNAIL. (GREATLY ENLARGED.)

Attached to the under side of the proboscis, near the end, is a soft circular pad. The presence of this attachment at once gives the clue as to how the moon snail penetrates the shell of its victim; for it seems to serve as a sucking disk, and by means of its holding power is the necessary purchase obtained to apply the pressure of the drill.

But the most significant feature is the pair of cutting jaws just within the tip of the eversible proboscis. Each jaw is a thin platelike blade of irregular shape and is fixed so that it presents a razor edge to its com-

panion, both working upon one another somewhat like a pair of shears. This dreadful instrument is a most efficient accessory. It is by introducing this into the drilled aperture that the moon snail becomes a monster. It literally hacks the helpless mussel to pieces. What really takes place is the deliberate fragmentation of the other. To be brief, the moon snail picks its prey out piecemeal.

And yet there are phases in the life of this creature that have a saving element. Great as are its vices, it is not entirely removed from virtue. Indeed, to depict only the darker aspect of its instincts would be unfair. Therefore, I shall try to bring into relief, also, that element of grace to which it would, no doubt, wish to lay claim. This is its foresight and consideration as a parent. The mother, with a precision born of patience, constructs a protective cradle for her young that is a marvel of dexterity.

Except for a difference in size, the female is in outward appearance exactly like her smaller mate. The mating season is in midsummer, and it is then that she makes her singular egg case. It resembles nothing so much as a thin, sand-encrusted, cracked saucer or bowl minus a bottom. Now the egg cases of the moon snails are familiar objects on many beaches; they are often washed ashore in thousands. Yet it appears that very few, except naturalists, are aware of their origin. But this ignorance on the part of the lay person is not without good reason. There is little about the egg cases to indicate their identity. Naturalists themselves, for that matter, have not been in the secret long. For, in works written in the past, but in a period when their

authors should have known better, we find unique descriptions, assertions that these are low forms of life belonging to various places in the animal kingdom.

An examination with a strong glass will reveal the sandy surface to be a skillfully wrought protective shell,

EGG CASE OF THE MOON SNAIL.

underneath which is a single layer of transparent globular capsules. These are arranged compactly, but in a roughly quincuncial manner. So small are they that there are more than sixteen hundred in the area of a square inch. But, mind, these are not the eggs themselves. The eggs are bodies still more minute. There are a dozen and more suspended freely in the humor of

each capsule. By careful and repeated measurements of the surfaces of sundry egg cases, I have computed the total number of eggs produced by the female in a single brood to be more than half a million.

The building of the egg case is a painstaking process. More often than not, the greater part of a day is given to this maternal task. The capsules are glued together in the mantle cavity from whence they emerge in a gelatinous sheet. As fast as it is formed, however, the mother covers the agglutinant surface with selected grains of the sand in which she is generally half buried. As the case continues to grow, she holds it close to her shell. Consequently, it travels completely around her, being molded into its peculiar shape by its circuitous excursion.

After the making of the case, the mother is no longer concerned with her young. She has labored to insure their protection during their incubation, but with this her interest ends. When her task is completed she moves away, abandoning her brood at their birthplace.

But she has done her work well, and the eggs have little need for further maternal care. For nearly a month the egg case is washed here and there over the sand and stones, and remains intact. Then the eggs are ready to hatch. And it is not until then that the egg case begins to crumble. The action of the waves assists in this disintegration; thus, at the same time, assisting in the liberation of the numerous progeny.

But what an extraordinary progeny! Here is no graceful dome but a flattened spire. It is just the merest fragment of a shell. Nor is there a muscular

foot to plow the sand. Instead of a crawler, it is a swimmer, a little, indescribable, transparent speck of jelly cavorting about in the water.

This is the larval stage. Thenceforward the young gradually assume a more snaillike appearance. It is well into the ensuing winter, however, before they can

EGGS OF THE MOON SNAIL. (HIGHLY MAGNIFIED.) THE INDIVIDUAL EGGS CAN BE SEEN AS THE SMALL BLACK BODIES CONTAINED IN THE LARGER CELLS.

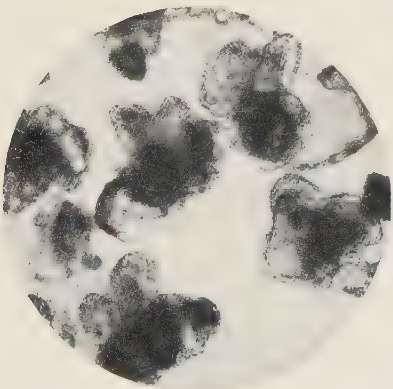
easily be recognized for what they are. But by the time their further development obliges them to pursue their course on the ocean floor, many thousands will have perished by the way.

What will happen to them, do you ask?

Well, some will become food for the barnacle, the clam, the sea squirt, and a multifarious but hungry host

of smaller creatures. But in the case of the majority, the finish will be in the stomachs of the selfsame mussels which serve as prey for the full-grown moon snail.

Now, to a certain extent, the two mollusks which I have here reviewed, the mussel and the moon snail, may be taken as representative of their classes. That is to say, the one is largely typical of the bivalves, or



FREE-SWIMMING LARVÆ OF THE MOON SNAIL. (GREATLY ENLARGED.)

pelecypods; the other is an example of the univalves, or *gastropods.* It is to be noted, however, that the habits of the various species within each class may differ considerably. For instance, not all pelecypods lead a stationary life; neither do all gastropods live by preying.

The pelecypod mollusks are, in fact, a very extensive group of animals which vary widely even in their structure. It is to this group that also belong the clam, the

scallop, the oyster, and other well-known edible shell-fish. Beside the name *Pelecypoda,* meaning "hatchet-shaped" foot, and which, by the way, is in many instances a misnomer, the term *Acephala* is used, indicating "without a head." Another name, *Lamellibranchiata,* in reference to the type of gills peculiar to these animals, has also been employed. But the terminology of science contains no name more descriptive or correct than the easily remembered, easily pronounced, and easily understood popular name "bivalve." For every animal in this class has two valves (the word "valve" meaning "shell").

Bivalve mollusks, unlike their univalve brethren, do not build egg cases. They do, however, lay eggs. These, as a rule, are not kept within the shell among the fleshy folds, and when they hatch they give rise to free-swimming young somewhat similar to those of the moon snail. The fate of the majority is likewise similar. It has been asserted by naturalists that probably not more than one in a million reaches maturity.

On the whole, the bivalves have acquired a more stationary habit of living than the univalves, but there are individuals among the former which can travel with remarkable rapidity. In speed and action the fastest univalve cannot match them. The scallop (*Pecten*) is one case in point. It adopts the singular method of quickly opening and closing its valves; thus propelling itself through the water in a jerky, butterfly sort of flight. The extreme case, though, is to be seen in the razor clam (*Solen ensis*). The characteristic "razor shell" of this odd-looking mollusk is familiar to every one who has visited a sandy beach. They are easily to

be collected by the hundreds. But to get specimens of the living animal is quite another matter. Burrowing in the sand to the depth of two or more feet, where they remain hidden most of the time, they are seldom seen. Yet even where one can be observed incautiously projecting from its burrow, it is not so readily captured. At the slightest jarring of the sand in its neighborhood, it takes alarm and immediately disappears. And it requires a rapid and skillful digger with a spade to catch up with it. Its quick descent in the sand is accomplished by means of its remarkable foot. This it extends downward into a point; then expanding the tip, the organ becomes wedged in the sand, enabling the animal to draw close the shell; and by this performance, quickly repeated, the razor clam makes a speedy retreat. Now sometimes the razor clam likes to take a swim. Here, too, the efficiency of its foot is displayed. With a flick of this organ the animal pulls itself spasmodically but swiftly through the water.

Although all bivalves are pelecypods, not all univalves are gastropods. (The word "gastropod" means "stomach foot.") Only two mollusks, however, are exceptions to this statement. These are the tooth shells, or *Dentalia,* and Nautilus, which belongs to those divisions known as the scaphopods and cephalapods, respectively. So in the strict sense of the word the term "univalve" has its limitations, but as it has come into such common use in reference to the gastropods, its employment is now generally restricted to these mollusks.

Now I have been so lavish with strange names and scientific terms that the reader is apt to have become

confused. Let me, therefore, hasten to set him right. It will be easy to do this by summarizing.

The *Mollusca* are divided into five classes. These classes, taken in the order of their supposed relationship, are respectively the *Amphineura, Gastropoda, Scaphopoda, Pelecypoda,* and the *Cephalopoda.* With the exception of the *Amphineura,* a group that includes the curious chitons and their allies, the modification of the *foot* is the basis on which these classes have received their various names. For it will be noticed that the terminations of the remaining four names refer to the foot. Thus, the *Gastropoda,* represented by the common garden snail, the moon snail, the periwinkles, and other mollusks bearing but one shell, usually spirally coiled, crawl on the thickened under surface of their bodies. That is to say, the foot. The *Scaphopoda,* whose shells are like little elephant tusks open at both ends, burrow in the sand or mud with a long wormlike foot. The *Pelecypoda,* to which belong the familiar oyster, clam, and mussel—bivalves all—are variously endowed in respect to the shape of foot, but the prevailing type is club- or hatchet-shaped. The *Cephalopoda* are distinguished among molluscs by having the foot modified into a number of so-called "arms" which encircle the head or the mouth. It is to this group that the squid, the octopus, and the pearly-shelled, chambered nautilus belong.

It is the class *Gastropoda,* however, that is the largest and most comprehensive of the five subdivisions. It far outnumbers the others, both in species and individuals. Moreover, it is among these that are found the only members of the entire group of mollusks which

have learned to breathe in the open air. The garden snail and the slug are outstanding examples. Once upon a time these quaint creatures were possessed of gills and lived in the water, like their relatives in the pond and sea. But now they breathe with lungs, and they are no more able to live under water, continuously, than any other air-breathing animal. The question, therefore, at once arises as to how this transformation was brought about. How, in the evolutionary progress of these creatures, came they so completely to change in their habits?

The truth is, no one knows. But men of learning have given this question considerable thought. And they have formed some very definite opinions. They have, moreover, given us evidence that greatly supports the apparent probability of their conclusions. One aspect of this evidence is well worth pausing here to ponder. At any rate, in so doing, it will enable us to get an interesting viewpoint of this problem.

This brings us again to the tides. As we have seen, the periodic rise and fall of the waters leave many animals exposed for a greater or lesser duration of time. Now there is much variation between the capacities of different shore animals to resist drying when exposed by the retreating tides, but these capacities are invariably in direct relationship to the positions the animals occupy on the shore. Thus, certain of the periwinkles (*Littorinidæ*) are found only high above the low-tide line. Some (*L. neritoides*) live in shady nooks just above high-tide mark. But there are some tropical members of this family (*L. varia, L. fasciata, L. pulchra*) that actually live in trees entirely out of reach

of the salt water. It will be seen, therefore, that the Littorinas are well on the road toward a land life. They are, in fact, gradually substituting lungs for gills.

That the Littorinas first acquired the habit of living out of the water through the influence of the tides is not unreasonable to assume. And succeeding centuries gave rise to individuals which were increasingly able to withstand long exposure to the air. But, while this may hold good in the case of this particular group which is essentially marine, there would seem to be some difficulty in accounting for those air-breathing

LITTORINA; A PERIWINKLE'S SHELL.

types which undoubtedly had their origin in fresh water. And those types, by the way, have so far progressed that they must have been a long time on the road; in fact, the first to start in the evolutionary procession.

But the answer to this is forthcoming. It is presumed that the age of the ocean since the earth assumed its present form is somewhat less than 100,000,000 years. Now, as is well known, the sea receives from the land in addition to other elements more than 60,000,000 tons of sodium every year. This substance, dissolved out of the rocks by rains and carried

in solution to the ocean by rivers and underground streams, there unites with its proper proportion of chlorine, the chemical union forming the salt of the sea. It becomes obvious, then, that as we go farther and farther back in point of time, the primordial waters become rarer and rarer in those earth-derived elements that make up the content of the present existing sea. In other words, to put it conversely, the sea became more salty with each succeeding age. Therefore, it is extremely probable that the early mollusks had their beginning in a fresh-water sea. And then, also, of course, as well as now, the tides prevailed.

Chapter IV

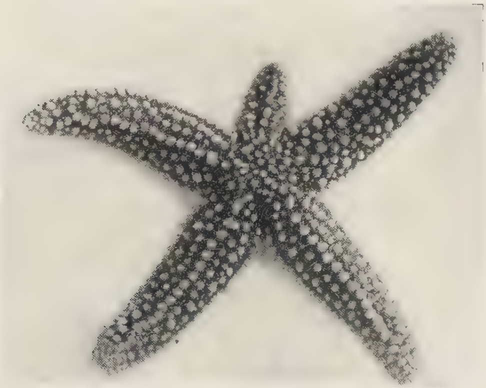
THE STARFISH AND ITS KINDRED

It is a curious fact that of all the great groups, or phyla, of animals which inhabit the sea, there is only one which is purely marine, which has no relatives or representatives on land. This singular instance is in that division of animals known as the spiny skins, or echinoderms: under which are classed the starfishes (*Asteroidea*), brittle stars (*Ophiuroidea*), sea urchins (*Echinoidea*), sea cucumbers (*Holothuroidea*), and feather stars and sea lilies (*Crinoidea*). Where, for instance, the lobster, the jellyfish, and the horseshoe crab are related to the terrestrial crayfish, the fresh-water hydra, and the garden spider, respectively, we find the starfish and its kindred to have not the remotest connection with any living forms out of the sea.

The starfishes are common to nearly every seacoast in the world. The most numerous species along the Atlantic shores of this continent are *Asterias vulgaris* and *A. forbesii;* the first named being found from the Carolinas to Labrador, the second from Massachusetts Bay to the Florida keys. They are nearly alike, except that the rays of the former are more pointed and the madreporic tubercle is of a uniform color with the rest of the animal. In the latter this tubercle is orange-

colored. Traveling in droves, as starfishes sometimes do, they range from low-water mark to depths of six hundred fathoms or more.

The brittle stars are so called because of their extreme tendency to break off their limbs when captured. They are much less abundant than the common starfishes, and their secretiveness makes them hard to find.



ASTERIAS; THE COMMON STARFISH. THIS INDIVIDUAL IS GROWING A NEW ARM IN THE PLACE OF ONE THAT WAS LOST.

Although some specimens live near the shore, they are for the most part inhabitants of deep water. Their very slender rays and their active wriggling movements give them the superficial appearance of a spider. Their outstanding difference from the starfish, however, is in having their limbs more or less loosely attached to the central disk, or body. In the starfish the rays are solid extensions of the disk.

Sea urchins, although differing in shape, are alike in

having no rays. Moreover, all are characterized by the great development of movable spines. They are sometimes called ocean hedgehogs, on account of their spiny covering. More sluggish than the starfishes, they seldom wander far from their accustomed haunts. Various species of these animals are found from high-tide mark to very great depths.

Sea cucumbers are creatures whose general appearance is wholly unlike the starfish and the sea urchin. But there are certain characteristics (of too technical a nature to be detailed here) they have in common with those animals which places them undoubtedly in the same company. They may roughly be described as sausage-shaped with a rosette of tentacles at one end. They are inhabitants of every variety of bottom; but the majority are found in the sand and mud which, like the earthworm, they eat for the organic particles therein contained.

Most feather stars and crinoids live only in deep water and are seldom found near the shore. The crinoids are generally known as sea lilies because of their general form. They have a long, jointed stalk, one end of which is attached, while the other bears the disk and featherlike arms of the animal. The sea lilies remain permanently fixed where they grow, but the feather stars, which at one stage of their life are stalked, detach themselves from this part of the body and swim about by means of their arms.

Thus I have given in the briefest form possible the general characteristics of the five classes of animals which make up the phylum *Echinodermata*. The complete life histories of by far the greater part of this

interesting and extensive group are as yet unknown. Indeed, even the full details regarding the lives and habits of our commonest forms are still unrecorded. For the young naturalist who is fired with the ambition to add his substance to the sum of scientific knowledge, he can not do better than to apply himself to the study of whatever type is at his convenience.

But this matter of convenience entails more than the mere presence of the subject in one's locality, if one is successfully to enlarge upon the knowledge of its ways. It is often that chance brings discoveries which perseverance has failed to produce; and that physical conditions for observation may also determine the measure of achievement. As a case in point, let me take the reader to a once favorite haunt of mine.

Formerly, in the vicinity of Harbor Beach, there stood well out in Hempstead Harbor the partly submerged framework of an old wreck. It had been a coastwise boat that years ago, on catching afire in the Sound, put into this harbor where she was beached and left to burn to the water's edge. When I first made its acquaintance, all that remained was the bulkhead, which was headed toward the shore, and a score or more of ribs still standing upright and trailing away from this point, those outermost finally losing themselves in the deeper water. The superstructure, of course, had entirely disappeared. Little remained but the bare skeleton of what once was evidently a well-built boat.

However, at that juncture where the keel and other timbers form the framework of the bow, there was yet in position a portion of the forecastle deck. This

was of a size just roomy enough to serve as a vantage point from which to view the details of the interior of the ancient wreck. The angle at which the hull settled was such that the greater part of this shelving woodwork was above the reach of the tides.

Between the tide marks—that is to say, in the space of about seven feet—the framework was covered with mussels. But their possession of the blackened timbers was disputed by the barnacle and the shipworm; for the fragmentary appearance of the hull showed clearly the presence of this invisible but insidious last-named animal ceaselessly gnawing at the vitals of the woodwork. In the higher levels of the transparent waters, every stick and stanchion stood out distinctly. From every part of the submerged structure there rose fronds of seaweed and hairlike clusters of hydroids. In the dark-green limpid depths could be seen dull-glowing patches of red, like splashes of molten iron beginning to cool. They were sponges; and their vivid hues invested the homely old hull with an exotic charm. Many bizarre forms were represented there. From the ascidians, or sea squirts, which looked like warty growths, or excrescences, on the wood, to that delightful creature, the starfish, which is an adornment to whatever surrounding it may be in, the profusion of forms seemed to be as infinite as it was various.

Such is the general, and necessarily imperfect, picture of what, to me at least, was a marine paradise. Whether or not this mass of rotten wreckage would have excited in others the same emotions that filled me, I do not know. But many were the splendid hours that fell to my lot as I lay under the summer sun peering

into those mystic depths. Majestic, rapturous hours! Strange fishes slinking out of the shadowy maze, catching sight of my slightest movement, retreated ghost-like into the deep blue. Others, less timorous, dissolving into view would hover near, apparently undaunted by my presence. Often, however, I would frighten them with a wild flourish of my arms to see how far the silvery gleam of their scales could be followed into the emerald depths beneath. And how alluring were those crystal waters! Frequently I would dive down into the inviting coolness of the limpid labyrinth to sit on some frond-wreathed beam as long as the breath within me lasted.

But that delightful rendezvous no longer exists. With the exception of some half dozen rotting timbers which are exposed at low tide, the hull has since disintegrated and its water-logged fragments are being fast silted over on the harbor floor. It was not the force of wind and waves, however, that brought about its reduction, for this is a well-protected inlet; the factor was far more subtle, but none the less puissant.

It is well known that the destruction of maritime property by the shipworm (*Teredo*) is surpassed by that of no other marine organism. Though commonly called the "shipworm," this creature is not a worm; it is a mollusk; that is to say, a near relative of the clam, the moon snail, and other shellfish. Its wormlike form is due to its boring habit. Each female is capable of spawning about a million young; and these, unlike the adult which remains fixed in its burrow for life, are very active swimmers. When they

grow to the size of a pinhead they seek lodgment on pilings and other submerged timber, and there start their burrows. For a short distance from the entrance, each burrow is perpendicular to the surface; it soon turns, however, and aligns itself with the grain of the wood, although with more or less of a twist. Regardless of how numerous these burrows may be, the occupants never touch each other. Always there remains a thin partition between the individuals infesting the wood. The shipworm mines its tunnel to accommodate its growth. As the burrow increases in length it increases somewhat in diameter, but the original point of entrance always remains the same. This opening is so minute that it easily escapes notice and the infestation is generally not detected until the destructive work of the animal is well advanced. It is through this orifice that the shipworm thrusts out its paired, siphon-like tubes to strain the water for food.

Ever since man began to build ships and wharves he has had to contend with this diminutive monster. So effective are its ravages that it can ruin utterly within the space of a few months that which takes years of labor and millions in money to construct. In the upper part of San Francisco Bay the damage during the years 1919 and 1920 resulting from the activities of the shipworm has been estimated to exceed $15,000,000. This estimate was placed solely on the damage to docks and piers; what the total losses to shipping and harbor construction of all our ports during every year may be is not determined; it is agreed, however, that the amount is so stupendous that its significance would be lost on the average mind. Here-

tofore the greatest losses seem to have been sustained on the Pacific coast. Whether this has been due to a greater proportion of wood structures in those waters which were subject to infestation, or whether it was due to other natural conditions, is not clear; at any rate, there has been a striking increase in the prevalence of this pest in the shore waters of the Atlantic coast. It has, in fact, made its appearance in extraordinary numbers in all congested harbors along the Eastern seaboard as far north as Long Island Sound. Within the next few years, at its present rate of increase, it will have established itself in every seaport and harbor in the United States.

It threatens not merely man's property, however; it is a real and constant menace to his life. Indeed, I think it may be said without exaggeration that indirectly the shipworm has sent more men and boats to the bottom of the sea than have been wiped out of existence by the direct violence of storms.

However, the destruction of the old hull was compensated for by its picturesque appearance and the fantastic beauty that the living forms lent to its vanishing shape. But, although the beauty of the spot was quite irresistible, other attractions also took me there. From my station on the little platform, I could study with the greatest ease the habits of my favorites in their natural surroundings, and follow the growth and succession of various types as these were manifested throughout the different seasons. It was, in truth, an ideal observatory.

Now, needless to say, the starfish, which in point of numbers was second only to the mussel, engaged a

large share of my attention. If you know the starfish, you will readily guess why it elected to make this place its home. It was because of the ever-constant supply of food covering the crumbling ribs. But as this history is being written primarily for the reader who knows little or nothing of our sea folk, I shall amplify the preceding statement; there is more of interest in it than the bare assertion implies. And as I proceed toward this end, we may find it of further interest occasionally to linger by the way.

Once again I see myself installed in the spot beloved of Asterias. The late September sun blazes through a listless air that as yet gives no hint of the frigid days which are soon to follow. But the heat, so oppressive on shore, is here tempered, not by zephyrs from the Sound, for there is not the slightest ripple in the harbor, but by the colder expanse of surrounding water. The tide is rising and has nearly reached its highest level.

Starfishes awaiting the return of the tide can be seen everywhere: some are crammed in crevices, others have wedged themselves in companies of several into nooks that would apparently limit the free movement of a single individual, and not a few are suspended motionless by the tip of a single ray from the under side of the dripping bulwark. These stragglers, slowly moving at best, while having been intent on their various occupations near the high-water mark, were left behind by the falling tide; and now, incapable of efficient locomotion out of their natural element, they remain inactive until its return. In the water below, seemingly scattered more numerously than the stars in

the sky, starfishes in various stages of growth are clinging to or crawling over the mussel-laden framework. By the bright orange button, or madreporite, near the center of each animal's back, and which each individual without exception carries, I recognize them all as belonging to the same species, *Asterias forbesii.*

Directly beneath, just within reach, I see one unusually large creature. It measures easily a foot across. Although long familiar with the appearance of Asterias, I cannot refrain from lifting this interesting specimen to examine for the thousandth time its curious details. For, be it known, the starfish is in many respects unique among animals. Simple as it is constructed, it is a never-failing object of wonder to the novice and to the experienced naturalist alike.

Perhaps its most outstanding departure from other animals is in the method of its locomotion. Laying this creature upon its back, I observe its efforts to right itself. It would seem that on account of its rigid structure it would have some difficulty in accomplishing this feat; but it can, in fact, perform some remarkable contortions in spite of its apparent inflexibility. For a few moments it remains the picture of helplessness. Flanking the deep groove that starts at the mouth and extends along the middle to the tip of each of its five rays is a forest of little transparent tubular processes. These slender processes are about three-fourths of an inch long, contractile, and very elastic; they are terminated by a well-formed sucker, an expansion by means of which they can be firmly fixed to any solid surface; they are, in fact, the ambulacra, or so-called tube feet, which are the actual organs wherewith the animal

moves about. Now in turning over, it brings its tube feet effectively into play. Twisting one or more of the rays on one side until their tips are bent under the body, so to speak, the tube feet at the extremities are thereby enabled to get a hold of the wood of the platform. Then by the successive attachment of the tube feet following farther inward on the rays, the starfish pulls its bulk gradually but completely over. The whole movement occupies a little less than a minute.

Beyond this effort, it makes no further attempt at any extensive maneuvering. Seemingly unable to use its sucking feet on a dry surface, it remains on the spot now well wetted by its dripping body. Yet its perturbation at being out of its natural element is quite manifest. On the under side of the tip of each ray can be seen a tube foot, noticeably delicate and without a sucking pad, extending here and there and then retracting, as though carefully exploring the region within its immediate radius. This operation is strongly suggestive of a blind person feeling around with a cane. Nor is the comparison incapable of further development. For, although able to distinguish light from darkness, the starfish is, in the usual meaning of the term, blind; but the suckerless tube feet are in every sense of the word its feelers. These latter, by the way, in spite of their resemblance to the true tube feet, are never employed as such; they are used only as organs of touch. Strange—is it not?—that this creature has five eyes—one at the extremity of each ray, a minute crimson speck—but cannot see; is equipped with multitudinous feet, but is unable to progress faster than three inches in a minute. Nevertheless, notwithstanding its limitations, it tra-

verses considerable distances; and to one unaware of the method of travel, its migrations are accomplished in an incredibly short time. The truth is, it appears rather poorly favored when compared with other rovers; but it gets there just the same, as we shall presently have an opportunity to see.

Before replacing my pretty starfish in the water, I do not neglect to examine its upper surface for caprellas and sea spiders and other minute creatures which are sometimes harbored there. Ofttimes this proves to be a profitable hunting ground; but in this instance it is barren of these guests. All that is revealed under the searching scrutiny of my pocket lens is the dark-purple exterior armed with short, blunt, calcareous nodules, or spines. They are encircled at the base, and not infrequently covered, by a cluster of tiny pincerlike appendages. These are the pedicellariæ; they are plainly adapted to seizing and holding, and their principal use seems to be to rid the animal of foreign substances such as certain seaweeds and other growths that have a tendency to affix themselves to hard objects. Less conspicuous, because of their great transparency, are numerous teatlike projections arising between the spines, which form part of the breathing system of the starfish. Except for their smaller size, they somewhat resemble the tube feet minus their suckers. Bending to and fro, they are constantly in motion, seeking to extract the oxygen necessary for the animal's support from the surrounding film of water. Thus it will be seen that the starfish veritably carries its lungs on its back.

But the most striking thing, in appearance at least,

is the brilliant orange tubercle called the *madreporite*. Lying near the rim of the central disk, at the angle of two of the rays, this rounded prominence is set out in vivid contrast to the rest of the body. Its gaudy color and exquisite conformation make it no mean adornment to the otherwise rugged exterior. It is a miniature replica of some exotic brain coral. In structure it is porous. It is, in brief, a filter. Its purpose is to strain the water which is taken in by the starfish and used to distend the tube feet when it walks.

Lifting Asterias from the platform, I drop it into the water and watch it sink slowly toward the bottom where it becomes nearly lost in the dark haze that all but obscures the verdant floor. Its position, however, is marked for a few moments by an ascending shower of bubbles, greenish-cast pearls arising in diminishing numbers to break at the surface with sparkling brightness. The soft, pleasing murmur of the bursting beads finally dies out and my attention is directed to the more visible parts of the hull. It immediately becomes evident that something of more than usual significance is taking place. Several feet below the mussels I see a number of starfishes clinging to the timber with their backs humped in the characteristic manner they assume when enveloping food.

What can they be eating? What is it that they have found in that region where only fixed vegetation seems to flourish? Certainly they cannot be vegetarians. And as for the presence of anything else of an edible nature, I am too familiar with this portion of the hull to have allowed it to escape me if it exists. Furthermore, it is impossible that they are enjoying a meal

which was obtained elsewhere; for starfishes are never known to transport their food; they devour it on the spot. Poising myself far over the edge of the platform to get a better view, I peer intently at the spectacle. No, nothing edible is to be seen in the vicinity. But under several of the nearest animals can be detected a filmy exudation appearing between the rays. It now becomes plain what they are about. Their attitudes are indicative of but one thing: they are spawning. These are females and they are liberating their eggs in the water to be fertilized by the male sperm cells, which are no doubt swarming here in invisible millions. Although the sexes are distinct it is next to impossible to tell from outward appearance which is the male and which is the female starfish. However, knowing it to be the rule among most low orders of animals that when an event like the preceding is taking place, the males are generally not far away, I look around to see if any unusual activities on the part of the others are to be seen. But nothing noteworthy manifests the fact that the males are busy.

Time passes. I am anxious to see what part the males play, if any, in bringing this wholesale delivery to a successful issue; for there is good reason to suspect that they are not wholly indifferent to the travail of the females. Although chance to a large extent determines the actual meeting of the eggs and the sperms, it would be a rare thing, indeed, if this chance were not lessened by the mutual behavior of the parents. But it grows dark; the tide is falling; I am reluctantly obliged to give up my watch.

Nevertheless, the next day finds me ensconced in the

same place ready to unravel whatever threads may present themselves. And I am compelled to add that repeated observations day after day bring me nothing new; each time I see the usual performance of the females but nothing to denote that the occasion is significant to the males. Yet my perseverance is not entirely without reward. I am soon to have more than my pains for my laborious steadfastness. But let me anticipate myself. Complete and successful observation of this affair is yet to be mine. However, in the following occurrence there is more than enough to convince me that if my suspicions are not altogether well-founded, I have come close to something so significant that it dwarfs the interest of the present inquiry.

Late one day when getting ready to abandon my post, I was arrested for a moment by something moving deep down in the bottom of the hull. It did not hold me for long, as it immediately lost itself in the gloom, and in the imperfect light I took it for some drifting clump of seaweed carried along by the incoming tide. Gathering together my trappings I climbed down to my little skiff which was moored to one of the stanchions in the capacious hull. No sooner had I seated myself than I perceived my mistake. The water was low, and my position in the boat afforded a nearer view of what was going on below. In the tenebrous depths moving in the general direction of the current could be discerned light, irregular masses outlined against the darker bottom like nimbus clouds in the moonlight. One of these patches carried upward well within visible range revealed its nature. It was a cluster of starfishes, each hanging on to the other. Then it was I

saw that the wreckage was fast becoming covered with them. They came singly and in groups; they came in multitudes. From whence they came I do not know; however, it is not improbable that the oyster beds near the mouth of the harbor would show evidence of their recent presence. Moreover all arrived by the same means. They were swept along by the tidal movement.

But why this exodus? Why this visitation to a spot which can give bare support in the way of food or foothold to such enormous numbers? Well, my guess is that this gathering of the clan had not to do with food but with fertility. It was one of those instances, not uncommon in the watery world, wherein marriageless females are nevertheless accompanied on their travels by attentive males.

Let us see. From the time the young starfish hatches out of the egg until several weeks later when it settles to the bottom, its appearance and its habits are totally unlike those of the familiar adult. It is a transparent cluster of fingerlike processes, so minute as to be barely visible; and it swims by means of short vibrating hairs, or cilia, which cover its body. During this period it is carried about by the tidal currents and waves or, as is more frequently the case, it holds close to the shelter of rocks, shells, seaweeds, and other nooks in the vicinity of its birthplace, thus lessening its chance of being swept out to the open sea where it would ultimately perish for want of proper food. But when the time for the metamorphosis arrives, when it loses its early, or larval, form and becomes a perfect, though tiny, starfish, it is no longer in danger of being carried out to sea; it is enabled to cling fast to solid objects with its

little tube feet. At this time, however, another and perhaps more serious problem presents itself; it must find food of such a nature as easily to be captured and overcome by such an insignificant and slow-moving mite as the starfish now is; for it starts out in the final stage of its life no bigger than a lentil. Herein is the first clue to the reason for the migrating of the sexes. No region of the ocean is more prolific of life than the shallower waters near the shore and in coves and inlets; and no region is more diversified. In that zone, from the high-water mark to a point several fathoms deep the sun's rays help to produce the greater part of that vegetation to which nearly all living marine animals owe their existence either directly or indirectly. This is to say the plants are eaten by certain animals which are in turn devoured by other creatures and these again may become food for others. Therefore it is not without purpose that the gravid females leave the less favorable depths to assemble in the region of the sunken wreck. In response to the maternalistic instinct they seek to disperse their eggs in surroundings where food will be plentiful for the forthcoming progeny. The adult males, in response to an instinct no less powerful, accompany the females in these migrations. For without their presence, without the certainty that the spawn is soon to receive that vital impetus which assures its further development, it is clear that the precautions of the prospective mothers will have been in vain.

Would you know what the young starfishes eat? Well, to enumerate all the things that go to make up their diet would be somewhat difficult; for, like the adults, they are scavengers—although fastidious ones

—and will hardly refuse anything which the taint of putrefaction has not made offensive. Although I have never observed them to touch marine plants even when starving, I have had no trouble in feeding healthy individuals in various stages of growth pieces of apple, pear, and other acid fruits; provisions strange and foreign to their natural larder. But, also like the full-grown animals, the little ones prefer living food. This they find chiefly among the young barnacles and mussels and other small shellfish.

Were it not for the gruesomeness of the operation, the manner in which they open the shells of their victims would excite admiration; for their perseverance is without parallel. Indeed, to one who knows the starfish only as an inactive, harmless, beach ornament, it will come as a surprise to learn that it can pull apart the valves of any shellfish its arms can encompass. The method is always the same. Straddling a bivalve, it humps itself high in the center, and fastens its hundreds of suckerlike tube feet to both valves. Then commences a steady pull. It is in reality a tug of war: the victim in the one case exerting its strength to keep its compartment tight-closed, and the starfish in the other slowly straining to force it open; but the starfish always wins. The luckless occupant cannot endure the constant pull. The starfish seemingly is tireless and finally the shell gapes open. Then an amazing act takes place. From out of its mouth the starfish protrudes its stomach, and envelops the animal within the shell. Nor does it withdraw this remarkable organ until its prey has been fully digested.

This concludes the essential part of my observations

STARFISH SEARCHING FOR FOOD. (PHOTOGRAPH TAKEN ON THE BOTTOM OF A TIDE POOL.)

of the common starfish as they were made in the old hull. Subsequent experience gained in other places and under other conditions has confirmed but not added to

the substance of what I learned among its wormy beams and stanchions. Here also must end the reader's acquaintance with that structure itself. My purpose in introducing him to this haunt has been fulfilled. Besides the background it has given us for the activities of the starfish, it furnishes a very important object lesson. To the seashore naturalist, no object, whether it be floating driftwood or submerged piling, is unworthy of attention. Whatever the tides inundate, regardless of its character, becomes fertile ground for him who deigns to dig.

Notwithstanding my obligation to proceed in the business of presenting those others who properly and justly claim a share in this history, it is not without regret that I leave this lovely scene. I fain would linger over its pleasing memory, over the image of its thousand stars bespangling the moldering framework or decorating the darkness of its receding depths, over the recollection of those fruitful, rapturous hours, ofttimes extending far into the night. To me this spot was as alluring in the blackest midnight as under the noonday sun. For, with the fading of the day, it had an ethereal splendor all its own; yet not unearthly, or unreal. The framework faintly glowing with a mellow light of phosphorescence became softly outlined in the watery void. And in the vastness of the silent night, the ancient corse no longer was a thing of rotting wood and wormy recesses; it was near and dear and human!

Chapter V

THE COMB JELLIES AND OTHERS

If one would fully acquaint himself with the various activities of the animals which frequent the shore, he should not neglect to visit this region after nightfall. Then it is, when the terrestrial world has settled to rest, that the water becomes the scene of a singular animation. On land, the setting of the sun is for the great majority of animals a silent signal for slumber. It is quite different with the creatures of the sea. With the exception of fishes and certain other higher forms, it is extremely doubtful whether marine animals sleep; and even in the case of those that are known to do so, it is the period of daylight rather than of darkness that they choose for this purpose. Throughout the night many creatures come close to shore in search of prey and retire before dawn. Observation at this time is comparatively easy; for if one be provided with a small electric flash lamp he can draw close to many wary crawlers, or stand quietly watching others which are utterly impossible of approach in the broad light of day. They seem not to be disturbed by the presence of the light; indeed, its rays are an attraction to not a few fishes, which disport themselves in glittering shoals within the luminous circle.

Although no season of the year is without its social activities, it is on warm summer nights that these are at their greatest height. During the dog days, the genial temperature of the shore waters makes conditions particularly favorable for the growth of plant life; this is reflected in the increasing abundance of animals, all of whom are ultimately dependent on the vegetation of the sea for sustenance. Moreover, the spawning of most shore dwellers takes place at this time, and as a consequence the water becomes extraordinarily populated. There is plenty to eat for all.

And how well they know it! Making their way in droves from the outlying reaches, the spider crabs (*Libinia emarginata*) approach the shore or swarm over the mussel banks, sometimes so thickly that the bottom seems literally covered with them. They live mostly on vegetable matter. These crabs are well named; they look like giant spiders, with their flask-shaped bodies and remarkably long, slender legs. The males are the larger, and often have a spread of over a foot and a half. Not only are these creatures the largest of all the true crabs to be found along our coasts, but another one of the spider crabs (*Macrocheira kämpferi*), found in Japanese waters, is easily the largest living crustacean of the world, measuring fully twelve feet over all. However, the spider crabs are less remarkable for their size than for the curious habit they have of masking themselves with plants and other growths. Sluggish and apparently stupid in their ordinary habits, in this one instance they surpass all other crustaceans in the display of reason: they will purposely select certain seaweeds, hydroids, and other

organisms and affix them to the hairy hooks on their backs, ostensibly for the purpose of concealment. Their show of intelligence in choosing only those materials that will bear transplanting and with reference to their colors has long occupied the curiosity of the lay person and the serious attention of the naturalist.

The spider crabs being vegetarian in their habits, it is quite evident that their presence among the mussels is a peaceable one; they frequent the beds to feed on a variety of small seaweed that grows on the shells. But the mussels are, nevertheless, the victims of nocturnal raiders not far removed in kind from the spider crabs. These are the sand crabs (*Cancer irroratus*) who with their powerful claws crumble away the margins of the valves, thus gaining an entrance to the occupants within. In these marauding exploits they are well attended by a tribe of smaller fry, the hermit crabs, which warily await just out of reach of the dangerous forceps until the owners have finished eating, when they at once pounce upon the fragments which the sand crabs have disdained to consume. Sometimes it happens that a hungry hermit crab in its eagerness or impatience approaches too near the formidable diner. Instantly it is seized and in spite of its attempt to retract as far as possible into its borrowed shell, this is broken away and the unfortunate inmate is plucked out piecemeal and leisurely devoured.

It must not be assumed, however, that the shocking exhibitions of ruthlessness are the sole reward for one's pains to visit the beach in the night; there are other compensations that go far to eliminate the unpleasantness of these contacts. Outstanding among these, with-

out a doubt, is the display of phosphorescent light by the various animals of the sea and shore. Especially striking is this phenomenon on a clear summer night before the rising of the moon. Here and there, among the pebbles and swarming over the swaying seaweeds, can be seen tiny points of bluish light; pale floating clusters of liquid fire are carried to the shore by the

BOLINA; A PHOSPHORESCENT COMB JELLY. (PHOTOGRAPH TAKEN IN THE WATER.)

waves to break upon the sand with a brilliant sheen; even as one walks, one's footsteps mark a softly shimmering trail, in which the quivering glow lingers for a while, hesitates, and then dies out.

These lights are variously emitted by minute crustaceans, comb jellies and worms. But by reason of the larger volume of light given off by each individual, and on account of their enormous numbers,

the comb jellies are far more conspicuous than the others.

The comb jellies, or *Ctenophora,* exist in every ocean. They are nearly as abundant in the arctic as in the temperate and the tropical waters. Of the several hundred different species which make up this group, perhaps less than a half dozen are known to other persons than professed naturalists. Even these few would doubtless have escaped common observation were it not for the extraordinary play of prismatic colors that is reflected from their bodies in the sunlight; for otherwise, because of their great transparency, they are practically invisible.

One particularly common comb jelly is the exquisitely beautiful "rainbow jelly" (*Mnemiopsis leidyi*) which makes its appearance on our Eastern coast during the hottest season of the year. In general form it is pear-shaped, somewhat flattened on two sides. Specimens six inches in length are not uncommon, but the great majority are more nearly four inches. Whenever one of these delicate creatures is encountered, others are almost certain to be in the immediate vicinity; they are gregarious—that is, they collect together and wander about by thousands. Although not a rapid swimmer it is a graceful one. It progresses with an undulating motion by means of eight rows of flat hairlike processes, or cilia, arranged in meridianal lines over the surface. The filmy gelatinous character of its body substance makes it extremely difficult to handle, and it cannot be lifted from the water without injury; yet, in spite of its delicate structure, it captures small fishes and crustaceans for its food, and has been known to devour

other comb jellies as large as itself. Exceedingly phosphorescent, its brilliant green light flashing intermittently in the night time makes a spectacle in the waters that is singularly entrancing.

Another ctenophore, less often seen, though common enough at times along the shores of New England, is the "comet jelly" (*Pleurobrachia rhododactyla*), an

PLEUROBRACHIA; THE COMET JELLY.

iridescent bubble of pink of about an inch or more in diameter. This little living transparent sphere courses its way here and there through the water, sometimes with a revolving and sometimes with a rotating motion effected by the paddling of its eight rows of cilia. But, more often than not, a curious exhibition accompanies these active movements. From what appears to be two nodes, the size of a pin's head, situated on opposite sides of the sphere, there will be extended and retracted, suddenly or gradually, as the case may be, a pair of threadlike streamers fringed along one side for their whole length with long waving cilia. As these slender

and gauzy plumes elongate, they trail behind the swimming animal in graceful undulating curves until they reach the amazing length of twenty or more times the diameter of the body.

At one pole of its body is the mouth, a narrow, slit-like opening; at the other is a small area in the center of which is the so-called "eyespot." This eye, however, cannot see as the fullest meaning of the word would imply, being sensitive only to light and darkness. Yet, notwithstanding, it seems to be aware of the approach of danger, for often the presence of a moving boat or other commotion in its neighborhood will cause it to disappear toward the bottom.

Now it will be noted that in the two forms just reviewed, the motor appendages, or cilia, by means of which they swim, are arranged in eight rows. In all ctenophores these rows run in a direction with the longitudinal axis of the body, and it is from their fancied resemblance to combs that the early observers assigned to the members of the entire class the term "comb jellies"; hence, their systematic name *Ctenophora*, or comb bearers. But, although the comb jellies are easily recognizable by virtue of their swimming organs, this distinction is, after all, a very superficial one. They are classed apart from the true jellyfishes, or *Scyphozoa*, because of other very real and far more fundamental differences. Besides the fact that both sexes are united in one individual, the comb jellies may be said to differ from the jellyfishes chiefly in their method of reproduction, which is to say, their eggs hatch directly into free-swimming young who in appearance or habits are in no essential respect unlike the adults. That this is not so

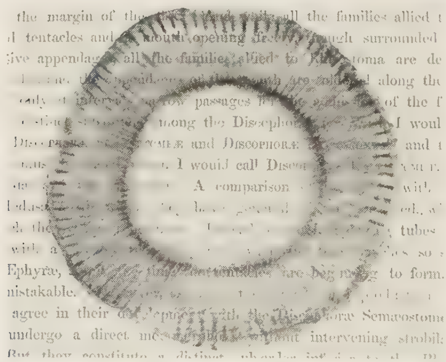
in the case of jellyfishes, will be made clear in what follows.

The large jellyfishes, or medusæ, as they are also called because of their tentacles which are suggestive of the Gorgon's locks, range from the size of a mere speck to several feet in diameter. But however diverse may be their dimensions, they all agree in general

PELAGIA; A JELLYFISH.

outlines and plan of structure. They are umbrella-shaped, or, rather, they are roughly comparable to a mushroom in which the stalk is superseded by dependent central organs, the mouth and stomach of the animal. As in the case of the comb jellies, many of the jellyfishes are phosphorescent; some are luminous over the entire body, others have light-producing organs of a more restricted type; and, also, like the ctenophores, they inhabit all seas.

In Hempstead Harbor two striking and uncommonly beautiful forms make their appearance regularly in the middle of May in each year. These are *Aurelia flavidula* and *Cyanea fulva;* and they sometimes occur in such enormous shoals that one has difficulty in making his way with a boat lest his oars strike them and mutilate their beautiful bodies. Storms sweeping in from the Sound with unwonted violence will occasionally



DISK OF A DRIED JELLYFISH. A TRANSPARENT FILM THROUGH WHICH TYPE EASILY CAN BE READ, IS ALL THAT REMAINS AFTER EXPOSURE TO THE SUN AND AIR.

throw them up on the beaches in masses, where exposure to the sun reduces them in a short time to an almost invisible film. This almost total obliteration by the sun is due to the relatively small actual body substance that constitutes the jellyfish; for despite their large bulk, they are slightly less than one hundred per cent water.

Aurelia, when full grown, is about ten inches in diameter. Its broad, transparent disk is somewhat like

a crystal dinner plate indented at the margin with eight notches. In each of these marginal notches, hidden by a hood, is a small tubercle containing the eyespot. A very short cluster of tentacles fringes the circumference of the animal. Four horseshoe-shaped sex organs arranged in a geometrical pattern around the center, well within the body, are a conspicuous and ornamental feature. By their color, one can readily recognize the sex of the individual: in the male they are pink, and in the female they are yellow. Aurelia revels in the sunlight. On cloudless days, when the water is smooth, it swims near the surface, reflecting the most delicate hues imaginable from its purple-tinged tissues.

In common with other jellyfishes, Aurelia swims in a very characteristic manner. Not being possessed of swimming paddles, or cilia, like the comb jellies, its mode of progression, quite obviously, differs from theirs. In short, it propels itself, not by the aid of organs adapted to this purpose, but by alternately contracting and expanding its disk. The action is like nothing so much as the partial closing and opening of an umbrella. This jellyfish never rests. The rhythmic movement of its body continues without intermission throughout its adult life like the beating of the human heart.

No less remarkable for its beauty is *Cyanea fulva*. This species may well be termed the "little brown brother" of the more widely known *C. arctica*, or sea blubber, the largest jellyfish in existence. Although more local in its distribution than the latter, and differing from it in size and color, its general appearance and habits are otherwise about the same. In our

Cyanea the disk is seldom larger than that of Aurelia's, but is more domelike; the incisions of the margin are more pronounced and are sixteen in number; only eight of these notches, however, contain eyespots. On the under surface is the central mouth, surrounded and hidden by four long voluminous veils that hang in loose folds. Near the margin, separated into eight distinct clusters, are the tentacles.

Here we come to what are perhaps the most singular organs in the animal kingdom. For one who sees our Cyanea the first time, as it floats serenely near the surface, trailing beneath its pulsating body these long and multitudinous threads, some of which are spun out for several feet and glisten like the finest gossamer, it is hard to realize that the jellyfish is anything but defenseless. But let one inadvertently expose his bare skin to the touch of the delicate strands and he will quickly withdraw with surprise. And if the specimen encountered be large enough, his surprise will not be unmingled with pain. The tentacles are, in fact, the creature's stinging organs wherewith it shocks and benumbs its prey. With these formidable weapons it literally combs the water for small fishes, crustaceans, and other animals upon which it feeds. They are contractile and extensible; indeed, the enormous length to which they can be extruded gives a considerable compass to the operations of the animal. But it so happens that Cyanea is not always hungry. Nevertheless, any luckless swimmer that grazes the paralyzing snare is seized and stunned just the same. It is soon released, however, and sinks to the bottom as if dead. Then, after a while, the effect of the shock seems to pass off, the

animal recovers, and swims away apparently no worse for the experience.

This remarkable capacity of the tentacles, wherewith the jellyfish is enabled to subdue its prey by stunning it, is due to hundreds of minute stinging cells that invest those organs. The cells are somewhat egg-shaped, with thickened elastic walls, and each one contains a coiled threadlike filament, one end of which is attached to the cell. The free end is pointed (in the case of some organisms it is barbed, in addition) and is charged with a highly irritant poison (believed to be formic acid). When organic matter, such as food animals or other edible material—for the jellyfish eats both the living and the dead—comes into contact with the tentacles, the cells in the immediate vicinity of the collision become excited and burst with such force that the poisonous filaments are driven into the object. It is to the noxious property of these myriads of poisonous darts that the paralyzing shock is due.

As I have already implied, the sexes are separate in the jellyfishes. The spawning season of Aurelia and Cyanea, which takes place in midsummer, is often marked by inordinately thick shoals of the congregating males and females. The eggs are carried in the maternal pouches until they have developed into little pear-shaped bodies (*planula*) covered with short cilia enabling them to swim. When they are liberated they wander around for a short time, but finally find their way to the bottom where they attach themselves to plants and stones. Then begins a series of marvelous changes in the growth and development of the jellyfish.

In attaching itself, the embryo does so on the narrow

end of its body. At the opposite, or free, end is the mouth, around which some little tentacles, usually sixteen, soon make their appearance. These latter are armed with stinging cells, the extruded threads of which give them a bristled appearance. It now commences to take food, and, consequently, begins to grow; but it will be some time before its details can be seen without the aid of a very strong lens. This is known technically as the *scyphostoma* stage.

As the scyphostoma grows, it lengthens considerably. At the same time an encircling constriction begins to make its appearance just below the base of the tentacles. Then gradually others appear in succession at regular intervals down the whole length of the animal. Finally, so deep do they become that the little jellyfish is segmented and now looks like a miniature stack of shallow dishes. But in the meantime another change takes place. The topmost, and first-formed, segment loses its tentacles, and the margin becomes deeply indented. The remaining segments then in turn develop similar indentations on their circumference, and the whole now assumes a decided plantlike appearance. This later form that these transformations have wrought is called the *strobila*.

The number of segments, or, more properly, disks, on a single strobila may reach as high as thirteen or more, but generally the total is less. The constriction separating the uppermost disk eventually becomes complete, and the liberated part, called an *ephyrula,* inverts itself and swims away. In a short time it grows tentacles, and becomes a perfect, though tiny, jellyfish less than an eighth of an inch in diameter. Following the

departure of the first ephyrula, the others soon detach themselves to pursue their individual ways. They will continue to grow, and in their turn produce eggs, until six months later, when their cycle of life is complete, the autumnal storms will have brought about their death and disintegration.

STROBILA OF AURELIA.

Regardless of their common name, "jellyfishes" are not, in any sense of the word, fishes. They, together with comb jellies, belong to a very different and far lower phylum known as the *Cœlenterata,* a division of the animal kingdom that includes also the plantlike hydroids, the anemones, and the corals. Nor must it be inferred that all jellyfishes develop in exactly the same way as Aurelia or Cyanea. Some there are which

start out in life as a spherical swimming egg, called a *planula,* and later become branching hydroid colonies; in other species, neither the colonial nor the strobila stage marks their metamorphosis; they pass without alternation of generation directly into the ephyrula state.

Notwithstanding that many of the comb jellies and jellyfishes are luminous, they are not essentially creatures of the night. It is true that some species among the latter never liberate their eggs until after the sun has set; however, it is equally certain their eating habits are not regulated by the sidereal alternation of daylight and darkness. Yet it is the night that reveals them in their most peculiar splendor. If by day the witchery of these resplendent forms is overwhelming, what shall we think of them at night when the fulgor of their mysterious lanterns flashes forth in the inky depths like pale-blue comets or streaks past with the similitude of shooting stars in the moving tide?

In general it may be said that little is known about the nature of animal light, and the luminous property of cœlenterates in particular is still an obscure subject. Indeed, even the life histories of only a few jellyfishes themselves are completely understood. One who would aspire to explore in a most interesting and an undeveloped field cannot do better than to give his attention to the cœlenterates, a group whose members easily rank among the most beautiful of all the living wonders.

Chapter VI

SOME FRIENDS IN ARMOR

If it so happens that the tide is favorable, the early light of an August dawn not infrequently finds me resting athwart the stern of my little boat, idly drifting in the shallow waters close to the harbor shore. Here the placidity of the sea, the companionable cries of the breakfast-hunting crows and gulls circling above the beach, the cool morning air dissolving the rising mists that hover along the cove, conspire to give an ardent glow to the enthusiasm with which I pursue my ambitious quest. For on the present occasion whereof I write, my early morning adventure has a more definite object than that of general observation.

Still, the familiar, pleasing details of the scene do not escape me regardless of the smaller compass that requires my attention. Even the sea seems now to be in its most delightful mood. Later, when the full heat of the day sets in, my motionless, open boat exposed to the direct rays of the seething sun becomes a veritable griddle; but in the present propitious hour, the temperature stirs the blood. And as I gaze into that wonderland over which I float, its serene and refreshing aspect quickens my very perceptions.

Among the water grasses and swaying seaweeds, I

catch the flutter of a flatfish as it makes its low leap across the rippled sand. The starfish, the moon snail, and the comb jelly, too, hold forth in the watery haunts; and there comes and goes a host of others.

Nearer is a pebbled area barren of vegetation. Here among the mussel clumps an occasional oyster can be seen with gaping valves competing with its neighbors for the microscopic harvest of the water. Almost within reach of my hand a low, sinuous mound slowly extends its length. The mole of the land has its representative in the sea. This tortuous trail is formed by the labor of the young horseshoe crab. Resting on the bottom, which it simulates with astonishing realism, is a squid. Unintimidated by my immobile presence, it watches with its great lugubrious eyes the approach of a shoal of killifishes. The minnows move in rhythmic progression, casting a stippled shadow over the gravelly floor, unaware of the danger that lurks beneath them. For an instant they hesitate—too late! The weird apparition suddenly darts into their midst, dispersing them in all directions; but not before it has seized several stragglers in its terrible arms. With a vicious snap of its beak, it speedily exterminates them. Not content with one victim, which would be fully ample for its meal, the monster ruthlessly destroys what cannot possibly serve its needs.

What manner of instinct is this that gives such scant consideration to the conservation of life, an instinct the primary impulse of which is an extravagant lust for killing? For a moment, forgetting the dictum of nature which properly holds that many must die so one may live, forgetting that awful equilibrium in which

there is maintained a just proportion of life through the ferocious but necessary medium of the stomach, and forgetting that here is but an operation of a benevolent law which determines the survival of the devourer to be in direct dependence on the unfitness of the devoured, I look upon this rapacious butchery with horror.

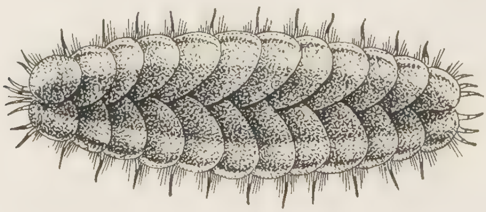
A dreadful fascination holds me, and with rapidly beating pulse I lean far over the rail. The movement, however, betrays my presence, and the animal on perceiving me takes alarm and slinks away, leaving in its trail an inky cloud.

My attention is now drawn toward a spot near by a small clump of mussels, where in the uncertain haze caused by the retreating squid I catch now and then the fleeting glimpse of the agitated movements of a young moon snail's shell. At once I recognize the object of my early visit to the seashore. It is the little hermit crab (*Pagurus longicarpus*).

Here he comes, now! Crawling actively over the bottom, he pauses from time to time and scrapes the sand in search of a morsel of food. From his busy claws comes the glint of the morning sunshine, and on the texture of those members there is a delicate iridescence produced by the diffraction of light. Soon he spies a dilapidated whelk shell half buried in the silt, and cautiously advances toward it. Its size is nearly equal to the one he carries; its decrepit condition, its calcareous incrustations, to which small seaweeds have anchored themselves, show that several summers have passed since it was instinct with life. After a preliminary frisk with his long threadlike feelers, he quickly rolls it over several times, giving the exterior a rapid,

but thorough, examination. Then deftly inserting his great claw into the opening, he explores the interior.

A scale worm, clinging just within the glazed entrance, seems evidently not to concern him. The crab's pressing occupation now is to determine whether or not these precincts contain something more formidable—perhaps a member of his own tribe. He finds it free from these, however, and prepares to take it over. Grasping the rim with his pincers he is about to with-



POLYNOË; THE SCALE WORM.

draw from his old shell and transfer to the new-found one when his antennæ fall across the worm. This causes him to hesitate. Oh, well; no matter. There seems to be room enough for two. So, without more delay, he vaults over swiftly and nimbly into the other shell.

Possession is followed immediately by a momentary disappearance whereupon all but the tips of his claws are hidden from sight. Soon his fore body emerges, and by the aid of the currents that wash the gill cavities, he sends forth a stream of particles consisting of the sand and débris that have filtered into the recesses of the scurfy ruin. The operation of retreating into

the interior and coming forth to eject the rubbish is repeated several times, during which he does considerable squirming in the effort to adjust himself to the convolutions of the shell.

After these precautions against insanitation and discomfort, the crab, with his flexible hind body firmly wrapped around the columella, or inside spiral, extends his legs and walks alertly away.

Now, in the strict sense of the word, the hermit crab is neither a hermit nor is he a crab. One may forgive the original nomenclators for misnaming this animal; in their rude system everything that carried claws was called a "crab." But the fact that they have bequeathed to posterity the misleading appellation of "hermit" is entitled to scant courtesy. Indeed, the fancied resemblance of the shell of the hermit crab to the shelter of a hermit is no more analogous than that the shirt on one's back is one's home. Nor is he averse to the company of his fellows. At no time does he lead a life of seclusion. Furthermore, among other of his un-hermit-like attributes, as we shall have occasion to discover later, is his fondness for female society in particular. Yet this instance is a trifle to some of the blunders of popular nomenclature; therefore, I shall pass it without further comment, lest I be accused of weighing hairs.

But his claim to membership among the crabs, hanging as it does by a still more slender thread, is a serious matter, and cannot be dismissed so easily. The two great groups into which the higher crustaceans are separated bear the scientific names of *Macrura* and *Brachyura;* meaning, respectively, "long-bellied" and "short-bellied." Of those crustaceans who are mem-

bers of the suborder *Macrura*, the lobster and the well-known fresh-water crayfish can be cited as the most familiar types. The distinguishing feature that places them in this division is, as the name implies, the possession of a long cylindrical abdomen, or hind body.

To the *Brachyura* only, belong the true crabs. And these are distinguished by the inconspicuous flat hind body reflexed along the under side of the thorax, or fore body. A common example of this division is the edible, or blue, crab of our tables.

These distinctions, by the way, are not arbitrary arrangements made merely to suit the convenience of the systematic scientists; for the most superficial acquaintance with comparative anatomy soon reveals that the crablike animal differs more greatly from the lobsterlike individual than does the dog from the cat. It is therefore because of this anatomical, or, to use a more correct term, this morphological difference that the hermit crab is incontestably removed from the brachyurians, or crabs.

However, regardless of those general features of his hind body that cause him to be set apart from the crabs, he is by reason of a striking modification of the form and function of this part of his anatomy peculiarly distinguished from all other creatures of his kind. Indeed, it is on this account that some writers have relegated him to a distinct group of his own, known by the name of *Anomura*, the "nameless bellied"; for his unusual hind body not only makes him notorious among crustaceans but places him among the curiosities of nature.

Unlike the fore body and its appendages, which are armored with a hard, tough crust, the abdominal region

of the hermit crab is soft, weak, and defenseless; it is invested with a thin membranous cuticle of a texture so delicate that the slightest abrasion will rupture it; an injury to this tissue is almost sure to prove fatal.

MALE HERMIT CRAB REMOVED FROM HIS SHELL; SHOWING THE SOFT UNARMORED HIND BODY.

Beginning at the very slender waistline, the bulging paunch assumes a spiral form and tapers toward the tail, where it is terminated by an aborted caudal fan, the use of which assists the crab in maintaining a grip on his borrowed shell. It is here that the intestinal

tract ends. Two other appendages are found on the left side, and a glance at their location and structure leaves no doubt of their origin. They are vestiges of what were once highly specialized locomotor appendages in the ancestral form of this animal. But now these degenerated, feeble, bristle-fringed outgrowths serve an entirely different purpose. In the case of the male crab their chief use is for sweeping forward the stercoraceous matter deposited in the shell; in that of the female they serve the additional function of anchorages for her extruded eggs.

The only effective strength that the hermit crab is capable of exerting to secure himself in his shell is concentrated in a small group of muscles extending along the under side of the hind body, and it is for the purpose of retaining this hold that this region has acquired its remarkable formation. In short, his belly functions as an organ of prehension; that is to say, a grasping organ.

It is apparent from the foregoing that the crab is not only compelled for reasons of safety to adopt a defensive covering, but when changing from one shell to another he also must act with the utmost dispatch if he is to avoid being seized by some predatory rover who may be near. Still, although it may be with good reason that the exchange is made quickly, it must be said that ofttimes it appears utterly without reason that the exchange is made at all. Now many motives, real or fancied, may inspire him to leave one shell for another, but there is only one distinct physical cause that absolutely forces him to seek a new covering. This cause arises from the simple fact that the crab grows.

The hermit crab lives long, indeed, if he survives the attacks of enemies and the dangers of parasitism for four summers' duration; but seldom does his life bear so extraordinary a charm. During the earlier part of this period he molts at least once—and sometimes, though rarely, twice—a year. Each molt is accompanied by an increase in size; and as a consequence he is obliged to find a larger shell. This shell needs never to be wanting for long. He has but to choose almost at random from the abundant supply around him, to find one suitably roomy. Yet times innumerable have I witnessed the abandonment of one for another, and for no apparent purpose other than to satisfy a crotchet. Moreover, he is not overscrupulous in the selection he finally does make. With so many to choose from, it would appear that instinct, if not reason, would determine the proper choice and impel him to select only that kind best fitted for his comfort and protection. He will, nevertheless, abandon a specimen which for convenience and capacity leaves nothing to be desired, and wedge himself into another so small that there is scarcely space enough to retract his fore body in time of extreme danger; in truth, he will adopt with equal facility the covering of a perfect shell or a fragmentary portion that passes as such.

Few instincts are more strongly developed than the instinct of self-preservation; in the crab, however, this instinct, exemplified by his preferences for protective coverings, shows some strange aberrations. I have found him encased in crumbling shells of rotten chalk, in a piece of spongy bone, in a bent ferrule from a jointed fishing pole, in a cumbersome hollow stone, in

a broken bottle neck and, more than once, in a remnant of a crushed shell which being little more than a girdle left his hind body as exposed as his head. Needless to say, his investiture with these heterogeneous materials reduces his capacity for defense, and exposes him to perils ordinarily improbable were he to provide himself with a more efficient form of protection. Could there be a more utter want in the display of intelligence? Oh,

HERMIT CRAB IN A BROKEN SHELL. THE DISINTEGRATING SHELLS THEY SOMETIMES USE LEAVE PORTIONS OF THEIR BODIES EXPOSED TO THE ATTACK OF ENEMIES.

for only a ray of reason! The faintest gleam would advance his welfare more in one brief moment than for him perpetually to grope in the darkness of aborted instinct.

Let us return to our wanderer. Having ensconced himself in his recently acquired shell, he now leaves the scene of the transfer in considerable haste. The truth is, his movements betray an unwonted agitation. His antennæ jerk spasmodically, and his nimble crawl ac-

celerates to a brisk run. It is evident that some singular attraction in the vicinity draws him onward. Ah, so that is it! I suspected as much. He has come upon the partially devoured carcass of a female sand crab, over and around which the mud snails (*Nassa obsoleta, Nassa trivittata*) and other small scavengers are swarming. The crushed carapace of the animal shows that it met its death under the spiteful heel of some fisherman, a stupid clown who, prompted by innate wantonness as well as by a desire to safeguard his lines from a bait pilferer, has in this ignorant act destroyed one of his most valuable assets; for the larval young of these creatures serve as the chief supply of food to many fishes.

Arriving at the table the hermit crab brushes aside several of the assembled diners, and with his great claw tears from the exposed flesh a choice portion which he retains in this member; then using his smaller claw he plucks from the detached piece shred after shred which he carries to his mouth. Daintily, deftly he performs this gastronomical feat with a fastidiousness almost humanlike; but notwithstanding this apparent refinement, the crab, like all animals which live precariously, gorges to surfeit. With but few exceptions the search for food among the denizens of the seashore entails an acute problem, a problem wherein the struggle to eat is surpassed in intensity only by the struggle to keep from being eaten. And, curiously, it is with the higher forms that this struggle to maintain life is the most bitter. The tiniest morsel has scores of competitors. When, through accident or otherwise, a death among one of the larger animals takes place, a veritable

windfall occurs; and the event seems to be telegraphed to the legions of the sea. Myriads hasten to the banquet. One and all, they come: the snails, the worms, the crustaceans. All, within the radius of the effluvial currents hurry to dispose of the corpse. Thus, in the economy of nature, each individual plays a part of the utmost importance; for it is through the desperate agency of hunger that the waters of our shores are purified.

After reducing the portion which he holds in his big pincer to a size small enough to be manipulated by the pair of fingerlike clasping appendages near his mouth, he passes to these what is left, and decides to move on. He does not proceed more than a few feet, however, before he stops and devotes some time in consuming what he can of the rest of his food; but, as he has literally bitten off more than he can chew, he finally ends by rejecting the remainder altogether.

Having satisfied the inner man, the hermit crab now gives some consideration to his external needs; for he is more or less of a fop, and will sometimes spend hours in grooming himself. Using either claw with equal facility, he rubs and scraps all parts of his fore body and its appendages. His time, however, is given mostly to the cleaning of his feelers, his eyestalks, and his legs, whereof the joint of the last named receive particular attention. Moreover, these toilet functions are very necessary; were he to neglect them in the slightest detail, his crust would eventually be overrun with plant growths which find in the horny composition an admirable holdfast; and their presence would indirectly cause his premature death by impeding his

movements and making it difficult—in fact, impossible—successfully to cope with the vicissitudes of a life that is hazardous at best. The result of this neglect is evident in the case of old crabs, many of whom, no longer retaining the suppleness of youth, have tufts of seaweed growing in those areas inaccessible to their chelipeds.

Hello! Who is this? Another hermit crab, attracted by the feast that our friend just left, has come within several inches of the primper. He is a great hulk of a fellow; and his shell is covered with a downy growth, for he carries with him a colony of cœlenterates (*Clava leptostyla*), which makes him look for all the world like a giant clad in furs.

Each catches sight of the other at the same instant. A momentary pause ensues. Then each, with his great claw extended, makes a sudden and furious rush for the other. The clash and rattle of their shells on the pebbles can be heard distinctly through the water as they come to grips and wildly seek an advantageous hold. Jabbing, cuffing, wrestling, they display an astonishing agility, encumbered as they are with their heavy shells, and the rapidity of their movements behooves one to watch sharply if he is to observe every detail. Now one is uppermost, now the other. Separating, they encircle one another with a sidewise movement, all the while keeping their big pincers thrust forward. Again they come together. They part. This time, however, the newcomer betrays a craven spirit; he precipitately leaves the field with a backward run. It were better, perhaps, to say he attempts to leave, for in his rapid retreat a stone obstructs his way, and the impact sends him topsy-turvy, causing him from fright or sur-

prise to withdraw completely into his shell and to block the entrance with his claws. In a trice the other is upon him. Seizing one of the exposed claws, he tries to dislodge him by tugging so violently and rapidly that the collision of their shells beats a tattoo. The persistent attack evidently arouses a spark of pugnacity in the poltroon, for he relaxes sufficiently to emerge and flourish a threatening pincer. This, however, is his undoing. He is immediately grasped by one of his rear legs, is jerked clear of his shell, and is tossed over the aggressor's shoulder.

The vanquished crab, now exposed in all his nakedness, curls his hind body under him and gropes around excitedly for some sort of object that will afford a shelter. None is within sight. It is now "any port in a storm." So, thrusting his hind body into an interstice among the pebbles, he assumes a defensive posture and keeps a wary eye on the victor who, meanwhile, following the unvarying procedure among his kind, is feeling around the inside of the empty shell with his formidable claw. After a momentary investigation he exchanges it for the one he carries. Obviously all is not satisfactory; in a very short time he returns to his own. Now, according to the rules of fair play, he should at least be generous enough to relinquish the spurned shell to the loser, as he can by no means avail himself of the spoils of the conquest and still retain the shell he bears. But fair play is no part of the hermit crab's code of ethics; therefore, he seeks to distrain the other who soon shows a disposition to press matters in order to regain his property.

Awaiting in vain for an incautious moment when the

HERMIT CRABS FIGHTING. (PHOTOGRAPH TAKEN IN THE WATER.)

victorious adversary would relax his vigilance, the dispossessed crab ventures closer. When within a few inches of the guarded shell, he makes a bold attempt to feint his enemy from his position by making a quick circuit around him at close quarters. The other is not to be caught napping, however. He engages the bereft one, and with a well-directed cuff, sends him flying backward.

These maneuvers are repeated again and again until it would seem there is no ending, or until one of the two tired of the contest, were it not for a circumstance that makes both of them forget their private quarrel. Two other males arrive in the vicinity. The first to spy them is our gladiator. He hurries forth to meet them, leaving behind the disputed shell. Then follows a skirmishing fight in which three hermit crabs are engaged.

This is an opportunity not to be lost by the defenseless one, so he speedily takes possession of his chattel. One would imagine that from his recent experience he has had his fill of fighting. Not so, however; he hastens to the fray and takes his part quite lustily, and the affair now becomes a battle royal between all four. For a number of seconds there is a confusing tangle of brandished claws and animated shells, while the staccato clicking of the latter rises in crescendo. Suddenly one of the warriors is knocked sprawling, upon which event the mass with one accord disintegrates and the crabs depart, all going their several ways. The fracas is over as suddenly as it was precipitated.

Let me here observe that of the hundred brawls I have witnessed between hermit crabs—in none of

which, by the way, have I ever seen an individual suffer a serious bodily injury—all were repeated without essential variation from the foregoing incident. Please note, however, that there is always a violent exertion on the part of the aggressor to dislodge the other, and when this is effected it is seemingly brought about by a tug that jerks the defeated crab clear of his shell.

That this exhibition of force is more apparent than genuine, I shall try to make clear by a brief analysis. If, with my fingers, I attempt to extract a hermit crab from his shell, one of two things is bound to happen. He either will throw off his claw or other appendage which is under tension, or he will suffer his body to part in twain. In the first instance, provided it is a cheliped or walking leg only that is concerned, the damage, particularly in the case of the younger animals, will be compensated for by the growth, or regeneration, of a new member at a succeeding molt. In the latter instance it is a graver matter, as the sundering of a vital organ results in almost instant death. Try as I can, however, it is impossible to remove the crab without recourse to methods less violent and of an entirely different nature.

Now no hermit crab is strong enough to dismember his antagonist, much less pull him apart. It therefore follows that even the largest and most powerful of these animals—whose strength, of course, can not approach that of my fingers—are utterly incapable of drawing an opponent from his shell by sheer force.

But, granting that the crab's strength is equal to the attempt, it is plain in the case of evenly matched individuals that the aggressor is as likely to wrench his

own limb from his body as to inflict this injury on his adversary.

Nor should the strenuous muscularity displayed by the crab be accepted without question. I have seen, times without number, this same agitated and frantic attack made upon empty shells, the same tugging and straining of forelegs inserted into a vacant interior, the polished nacreous walls of which could offer no possible resistance.

What is it, then, that causes the crab to leave a shell that he could easily retain merely by refusing to be coerced?

Well, I shall come to the point quickly. The hermit crab, acting solely by an instinct that he has undoubtedly inherited from his ancestors, is a notorious bully. Therefore, his display of force is only a fraud, a sham whereby he terrifies or startles his opponent out of his wits and out of his retreat. It is a question of nerves. The one with the most temerity wins.

Chapter VII

SOME FRIENDS IN ARMOR (*Continued*)

The peregrinations of our gladiator do not take him very far before he meets with a female. The latter, who is less than a third as large as the other, does not perceive him until he swoops down upon her from an ambushing frond of sea lettuce over which he has crawled. Instantly she withdraws completely into her shell and covertly watches him. When he reaches her he rolls over her shell, then stands above her waiting for her to emerge. It is not long before her antennæ are thrust out, followed immediately by her fore body. Whereupon he seizes her by a rear leg and retains a secure hold. The art of coquetry seems not to be absent even among the lowly, for she makes a great pretense at resistance and vainly endeavors to free herself. But he will not be denied. The rogue is a cool lover; ardency in his make-up, though not wanting, is without tenderness; he deliberately pulls her after him while he continues his perambulations.

Now and then they halt. In these periods he idly and mechanically scrapes the sand for atoms of food that he does not desire, but which she eagerly devours when they drift her way. By this time she has ceased her resistant efforts and resigns herself to him without

further protest. For the greater part of an hour they continue their sauntering; she in the meanwhile remaining in his tenacious grip. The monotonous watch makes me weary of waiting.

At length, however, his behavior changes. Facing her, he gathers her to him, and with a sudden movement brings her fore body clear of her shell. She accepts his embrace; and it is in this brief moment that a future generation of hermit crabs is assured.

These amatory embraces of the freebooter are resumed at intervals of a half to three quarters of an hour or more. But at no time does he release his hold on her leg. And he would, no doubt, continue to restrain her for the greater part of the forenoon but for the occurrence of the inevitable. The nuptials are rudely disturbed by the intrusion of a stranger.

The hermit crab who now comes upon the scene is formidable not merely in bulk but in appearance, also. Gauzy sprays of red seaweed float from the ends of each feeler, and from the joints of his fore legs streamers of green flutter at every step; all of which give him the aspect of a warrior bedecked in the panoply of battle. The presence of these vegetal growths indicates that he is old. Although old he may be, he as yet shows no trace of senility in his movements, a circumstance apparently not lost upon the other male.

Viewing the other's approach with no little perturbation, the apprehensive swain signalizes his concern with a menacing gesture of his free claw; then unceremoniously rolling his smaller mate under him, crouches with his fore body over her and assumes a belligerent attitude.

COURTSHIP OF THE HERMIT CRAB. (PHOTOGRAPH TAKEN IN THE WATER.)

The plumed knight does not even hesitate, but quickly engages the other. It is soon over. The more youthful one, receiving a painful pinch on the eyestalk, is overwhelmed by the onslaught and retreats ingloriously, leaving his mate to the mercy of the dauntless aggressor. He does not go far, however, before he recovers from the assault and decides to come back. Whether he returns to take issue with the big male, or to retrieve the female, it is not easy to say. Perhaps it is for both reasons. At all events, when he reaches the spot again, he halts in evident surprise at the sight that greets him. The handsome stranger, adding insult to injury, now holds the female and is paying assiduous court to her. To make matters worse she accepts the other's blandishments in complete indifference to her late lover's presence. Never was there more unabashed effrontery. What at first bid fair to become a conquest of violence has now resolved itself into an affair of the heart. The friendliness that she entertains toward her new gallant is only too plain to be pleasant. But the jilted crab ventures no visible remonstrance beyond nervously twitching his antennæ and flicking his claws, as if berating the fickle jade for her faithless conduct.

The turning tide, now fast coming in, makes further observation difficult. As I am curious to follow the history of the new-matched pair to its conclusion, I gather him with the decorated joints and plumed antennæ clinging fast to the female's leg, which my interference does not cause him to release, and place them in a pail of sea water to be transferred to a tank in my laboratory.

Although it may not be termed a hardy creature when compared with some other inhabitants of the sea, the hermit crab can be raised successfully and be made to round out the natural span of its life in the artificial environment of the indoor aquarium. It is here, there-

MALE AND FEMALE HERMIT CRABS. THE FEMALE IS THE SMALLER CREATURE PERCHED ON THE LARGER SHELL OF THE OTHER.

fore, that I propose to trace those phases of its history impossible of determination in its natural habitat.

There is strong reason to believe that the female can give birth to fertile eggs a year after the attentions of the male, but the time between mating and the emission of the eggs is generally much less. It is, however,

subject to considerable variation, and may range from a few hours to several weeks.

As was indicated, the mother attaches her eggs to the hairs of her abdominal appendages. Here they hang suspended like clusters of miniature grapes. The number of units in a cluster is not large, averaging perhaps not more than three hundred. Indeed, this number is surprisingly small when one considers the enormous broods of some other crustaceans. The blue crab, for instance, will produce in a single spawning 1,750,000 eggs. However, as the female hermit crab gets older her fecundity increases, but the increment is not enough materially to change the average given above. Her eggs are a deep cherry red in color, and in size no larger than the period ending this sentence. Each one is suspended in a membranous sac which in turn is attached by a short thread to a bristle on one of the forementioned appendages. Receiving no other care than an occasional brushing to keep them free from particles of dirt, they are carried for a fortnight before they are ready to hatch.

But in the meanwhile some remarkable changes have been taking place. By tearing apart, under the dissecting microscope, an egg which is but a day old, the differentiation of organization can be seen making its first appearance. That mysterious transformation, due to those unfathomed forces that cause the cells of all organic structures to assume their predetermined arrangement, has just taken place. Nearly a week later, examination of one of the spherical units will show that the yolk comprises nearly half of its bulk; while in the remainder of the egg content can be traced

the dim outlines of the nascent larva. Each succeeding day is marked by a gradual but very definite change in the embryo; until finally the wee animal acquires a segmented hind body, a large tail fan, and a pair of unstalked eyes. A more dissimilar offspring from the crawling adult could hardly be imagined. Its muscular, ringed abdomen and its broad tail now fit it preëminently to lead a roving life at any depth.

The moment for hatching comes. It has been signalized some hours before by a restless activity on the part of the larva in its apparent efforts to burst the two walls that confine it. Suddenly these are split lengthwise and the wriggling youngster emerges headfirst through the rent. It has no chance to linger as it is caught immediately by the respiratory currents of the mother and sent hustling away. A common impulse now seems to animate the brood, and within a few hours the remaining larvæ abandon forever the precincts of the maternal shell. The mother then detaches the swaddling clothes still adhering to her; and soon following the departure of her young she sends bag and baggage flying after.

Thenceforth each little crab pursues its uncertain fortunes alone. After a lapse of five or more weeks—during which it molts not less than four times, increasing in size and acquiring a more adultlike character with each shedding of its crust—it settles to the bottom and finds a tiny shell.

Such is the manner in which the hermit crab is ushered into the world. A rapid survey of his future shows that before the winter gales will have forced him into deeper water, where he will pass a dormant

existence, he will have molted once more and attained a quarter of an inch in length. The following summer will find him considerably larger, and by the third year he will have arrived at the period of sexual maturity; whereupon he will begin to take notice of his fellows, both males and females. From this time onward his feastings, fastings, fightings, and love-makings will continue. About two years later, realizing that the business of life is done, he will crawl under the shelter of a rock or frond of seaweed and die.

It is a natural impulse for us sentimental humans, when contemplating these lowly creatures whose employments have excited our interest, to exaggerate, somewhat, their mental capacities. Intimate knowledge of their ways, however, reveals the disappointing proof of a cerebration almost incredibly restricted in its range. But, regardless of the measure we may give to their intelligence, it is likewise a common experience at times to wonder what thoughts—if such an attribute can be said to distinguish invertebrate animals—are passing through some spineless brute's brain. We wish to be transformed by some magic power for a brief period, and to be reduced to the same mental plane in order to glean a glimpse of that strange psychology of another world, a world so mysterious that a moment's consideration leads us at once to recognize that here we have to deal with factors which have barely anything in common with human understanding—which is to say, the behavior of the invertebrate is governed by impulses that have little resemblance to intellectual faculties as we understand our own.

In truth, a thoughtful consideration of all lower-

animal intelligence brings the inevitable conclusion that we are powerless to penetrate even the outlying boundaries of that incomprehensible domain. As we descend from the intelligence of man, from his exercise of pure reason, through instinct, through so-called reflex action to the sentiency of one-celled organisms, we find that at each receding level the barriers to that awful frontier become more and more impassable.

The mind of humans or what passes for such among the lower animals is not a thing that can be subjected to the crucible or the retort. It cannot be weighed or measured. The instrument is yet undreamed of, which can register in the slightest the difference in kind or in degree between the mentality of mankind and the abysmal consciousness of the protozoan. The analysis of this thing which is without substance, form, or color, but which is nevertheless a tremendously real entity, is confronted by perplexities unknown to other investigations of the experimental worker.

Without wishing to anticipate myself, I am constrained to admit at once that the fragments I have gathered in regard to the status of the hermit crab's intelligence have added but little to the meager balance in its favor. Actuated entirely by instinct, prompted solely by the exigencies of the moment, it is in none of its pursuits guided by the faintest glimmer of reason. In the conduct of its courtship, in the search for food, in fact, in its entire deportment throughout the whole tenor of its life, it is motivated by a mind that is little superior, and in many instances inferior, in its manifestations to the movements of an automaton.

The primary attribute that distinguishes intelligence

as such, is memory. I need go no further than to illustrate by example the doubtful possession of this faculty by the hermit crab in order to substantiate the above indictment. The reader has seen that in the natural habitat of the crab, the waters of the seashore, a meeting of the males precipitates a brawl. It is the same on their introduction to the large tanks of my laboratory. In their new environment, however, these quarrels are not resumed indefinitely; eventually they resign themselves to a peaceful toleration, and share their quarters with indifference, if not with genuine amity. Beyond the usual attempts to filch one another's food, it is extremely infrequent that further hostile demonstrations occur. But what is more to the point is the fact that two males, when confined in a small half-gallon jar, never, after the first few hours of their acquaintance, renew, or rather exhibit, the slightest animosity toward each other. This circumstance, when considering the natural pugnacious propensity of the crab, is remarkable. What, therefore, does it signify? Does it mean that they have a memory for faces, so to speak?

Let us see. From a small circular jar in which two males have lived at peace for several months, I remove both and transfer them to one of the same capacity but of a rectangular shape containing a different arrangement of seaweeds. Immediately their former friendship is forgotten; a fight ensues; and one or the other generally loses his shell in the encounter. After they have settled their differences, I return them to the first jar; but no sooner do they come into contact than they again fall to, with the same result.

What could be plainer? The hermit crab either

has no memory or this memory in him is so feeble as to carry him only to the point of recognizing a strange environment. Beyond this he fails to apprehend anything else—not even the identity of his old companion.

If this inference be correct, we may reasonably expect to find that their transference to a corresponding container will result in no display of belligerence. And this is what we do find. The similarity of their surroundings misleads them into accepting the newer as their customary home; and as there is nothing unfamiliar in the newer place, they do not mistake each other for strangers. But this is not all. If I now drop a strange crab from one of the larger tanks into their presence, neither of the two original occupants seems to be aware of the addition until compelled to defend himself from the inevitable onslaught of the newcomer.

One more word regarding this matter. Near a north window in my study stands a rectangular aquarium holding about twenty gallons of salt water. In one corner of this miniature replica of the seashore bottom is a large brown anemone (*Metridium marginatum*) attached to a rock. Among the other animals with which the aquarium is stocked are several hermit crabs of both sexes. Conspicuous among these is a singularly huge male who by reason of his decrepit appearance and obviously old age drew from my children the alliterative, but fanciful, name of Hank the Hermit. Throughout the past winter Hank's great diversion, apart from exploring the nooks and interstices of the gravelly floor, and giving battle to imaginary enemies concealed in those retreats, was to make daily tours with monotonous regularity around the

glazed confines. In the direct path of these excursions stood the anemone. Now it seems not to be one of the traits of the crab when meeting with an obstacle to choose the more sensible and easier method of going around it; instead, his course is an attempt to go directly over it. This was Hank's intention whenever he came upon the anemone; but the contact of his feelers with the arms of the cœlenterate caused him to recoil with surprise. It may be interposed here that, although the touch of the anemone's tentacles is deadly to very small organisms, their potency is quite lost on the tough armor that encases the fore body of the hermit crab. Still, their power is considerable, as I have had occasion to learn by testing with the tip of my tongue; and I have no doubt, therefore, that the sting is as acutely felt with those delicate tactile organs of sense, the antennæ of the crab.

As the unpleasant contact with the anemone was assuredly one to be avoided, it might well be assumed that after three or four repetitions of his blunder, Hank would give that animal a wide berth. But three or four hundred repetitions failed to inculcate in him the slightest recollection of the dangerous spot. Time and time again, on his perpetual rounds he would blindly walk into the tentacles, never learning by experience or memory to avoid their painful touch.

Now, it has doubtless struck the reader long before this that it is a somewhat unfortunate, as well as a curious, circumstance for the hermit crab to be marked among all crustaceans by the double affliction of possession of a weak body and being obliged to bear a burdensome load throughout the greater part of his

life. That he was not a weakling, however, in the remote history of his race, is not only revealed by the internal evidence of his structure, but, if the statement of men learned in the evolution of life, that in the embryological and larval phases of animals are roughly recapitulated their ancient forms, be correct—and there is reason in abundance so to believe—there is more than a hint in the development of the living hermit crab that he did not always require a borrowed shell for his protection.

As fossil remains of crustaceans have been so meager, there is, of course, no way of picturing with absolute certainty the true appearance of the hermit crab's ancestor. Nevertheless, without going into tedious technical details, I will say that anatomical considerations alone strongly support the inference that the forerunners of the crab were endowed with a segmented hind body, and that they in general were distinguished by a much higher physical development.

It is, moreover, well known that the crustaceans appeared on this earth long before the mollusks. Therefore, it may be assumed that the utilization of dead shells by the crab is an attainment of a comparatively recent date. Nor is it unlikely that his propensity for secreting himself in crevices or crannies to await his prey, eventually led him to hide in empty shells. It needed only a further lapse of time for him to acquire the habit of carrying these advantageous coverings with him. But this restricted his movements. And the new mode of living lost him the pristine vigor of his body. What is more, the descent from the apti-

tude for a predatory life to the less alert existence of a scavenger has lost him his sagacity.

I am now obliged to make a painful admission. In summing up all the evidence, it is only too apparent that the hermit crab is an animal which long ago reached its highest development, and is now on the decline. In a word, the hermit crab is a degenerate.

Chapter VIII

MARINE GROVES AND GARDENS

As our knowledge regarding the nature of living things increases, it becomes more and more evident that the difference which is presumed to exist between the plant and the animal kingdom is at best an artificial one. That is to say, plants and animals are essentially the same. It is true that we recognize plants by certain characteristics, such as form, color, or development—characteristics not commonly found among animals—but, after all, a little reflection will show that these distinctions are more or less superficial. There is, in fact, no single attribute of fundamental importance to the life processes that can be said to belong wholly within the province of either kingdom.

The chief biological difference that distinguishes plants as such is in their capacity to utilize the sunlight in transforming certain elements into parts of their cell structure, and their ability to form organic compounds from elements existing free in nature or derived by breaking down inorganic compounds. This somewhat technical statement is only another way of saying that, whereas the truly typical animal can eat only substances already manufactured, such as plants or other animals, the plants, on the other hand, manufacture their own

food. But even this statement, although essentially accurate, is subject to qualification. Numerous exceptions abound. As a matter of fact there are some animals which are nourished like plants, and there exist certain plants which subsist only on food material already formed.

Now all this is not to say that what are commonly recognized as plants are animals in masquerade, or the reverse; it is, however, a way of stating that the gulf between them is far more apparent than it is real. Between the higher individuals of both kingdoms the relationship, of course, is not so generally obvious. But when we turn to the lowest of all living forms, the one-celled organisms, an undisputable kinship manifests itself. Indeed, there occur among these some which have identities that are neither distinctly plantlike nor are they truly animallike; rather they are both; that is to say, they are half vegetable and half animal. The little green Euglena of fresh-water ponds and streams is a classical example of organisms which, so to speak, are on the borderland. This pretty, but paradoxical, creature—if I may so call an organism which is also an undoubted plant—has given rise to considerable friendly controversy among naturalists as to its proper place in nature. Botanists as well as zoölogists claim it as their own.

But our lowest plants merit an attentive consideration quite aside from any of the foregoing reasons, for they are presumed to be the present-day representatives of the first living things to appear on this planet. The history of the earth is a thrilling record of vast and impressive changes, not only in the appearance and the

very structure of its surface, but in the succession of living forms which have inhabited it. Yet the simplest plants have outlived them all. Many there are that have persisted unaltered throughout the countless ages that saw the appearance and disappearance of mighty hosts of higher forms. Ancient as is animal life, the lowly plants probably antedate them by a period so great that in comparison the existence of the former would seem to be but of a day.

It is, therefore, with peculiar interest that we turn to the vegetation in the sea, for, as was pointed out in a previous chapter, this region was the probable source of all life. This vegetation, with very few exceptions, is comprised entirely of the lowest forms of plant life. Now this will appear strange to the reader whose limited acquaintance with the seaweeds has led him to look upon their varied and ofttimes beautifully branched fronds as structural counterparts of land plants. As a matter of fact, however, they have nothing in common with the higher terrestrial types. Seaweeds all belong to that division of plants termed *thallophytes*. All thallophytes living in water and obtaining their nourishment directly therefrom are further distinguished by the name *algæ*. It is for the reason that they are composed of one class of cells that algæ are the lowest and simplest of plants. In this respect, it must be borne in mind, the familiar flowering plants are totally different. The groups of cells which constitute the stem and the leaf and various other parts of the plant are vastly unlike in their character and function. In the higher forms of marine algæ, the vegetative body is called the *frond*. The disk or ex-

pansion of the base of the plant is the *holdfast*. This latter, although corresponding to the root of a flowering plant, does not, in the real sense of the word, perform the office of that member any more than the frond functions as a flower or a leaf. Roots absorb the nourishment for the entire plant. The nourishment derived by algæ from the substances held in solution by the surrounding water is due to the work of every individual cell composing the plant. In other words, beyond the fact that it is in physical attachment to its neighbors, each cell lives as a unit and without reference to the rest of the colony.

Notwithstanding its fundamental simplicity, the diversity in the structure of marine algæ is very great. In the lower orders a single cell constitutes the plant body. These forms are mostly microscopic. Next in point of development are those like *Cladophora,* which consist of single threadlike rows of cells. Then comes *Ulva,* in which is found the earliest type of expanded frond. Here the cells are arranged in a horizontal surface forming leaflike or ribbonlike expansions. In *Enteromorpha* there is a double layer of these cells which separates, giving the seaweed a hollow, or tubular, form. From here on the complexity increases until in *Sargassum,* or gulfweed, we see the most differentiated of all marine plants. In this form there are slender branching fronds bearing various kinds of lateral members, some of which are like ordinary foliage leaves supported on stems; others are round air floats resembling clusters of berries; and still other branches bear remarkable sex organs.

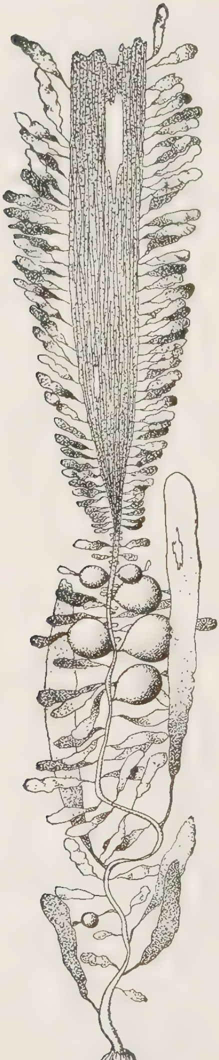
Not merely do the marine plants compare favorably

with those of the land in diversity of form, but they surpass them in linear size. The huge floating fronds of *Laminaria,* whose stalk develops great rootlike holdfasts, are frequently ten or more feet long. But the

SARGASSUM; THE GULFWEED.

LESSONIA; A LAMINARIAN SEAWEED.

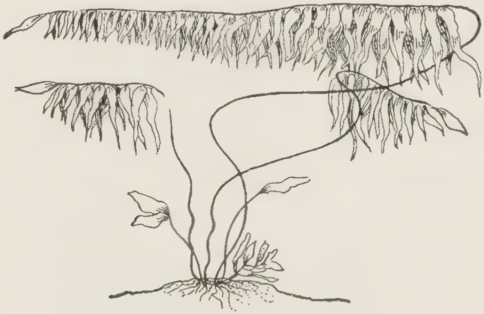
largest plant in the sea, and, for that matter, the greatest in height in the whole world, is an Antarctic laminaria. This extraordinary seaweed rises from the sloping bottom of the continental shelf with a frond nearly a thousand feet in length. Other large laminarian forms grow on the sea bottom like trees, hav-



EGREGIA; A LAMINARIAN SEAWEED.

ing thick trunks, numerous branches, and leaflike appendages.

Seaweeds also exhibit considerable diversity in color, and this feature has caused their being divided into four great groups. These groups, or subclasses, are the blue-green algæ (*Cyanophyceæ*), grass-green algæ (*Chlorophyceæ*), the brown algæ (*Phæophyceæ*), and the red algæ (*Rhodophyceæ*). These are again subdivided into various genera and species, and the num-



MACROCYSTIS; A LAMINARIAN SEAWEED.

ber of the latter so far known and classified is said to be several thousands.

As is the case with shore animals, the most favorable time for collecting or observing the range and distribution of seaweeds is during low tide. A walk along almost any shore at this time will show that these humble forms are as particular in their choice of locality and character of their neighborhood as are the higher plants of the land. Just at the high spring water mark will be seen some sturdy types of a short, stubby growth, which seem equally at home out of the

water as well as in it. Living here for many generations, they have attained, as the result of long-continued exposures by the intermittent tides, an un-

ENTEROMORPHA; A GREEN SEAWEED.

usual hardihood for sea plants. Others which have more recently taken to living here exhibit traces of the fight to maintain their new positions in their emaciated and starved appearance. They have not yet acquired the ability to withstand prolonged absence from the

water. Lower down, these same plants can be seen growing; but in this place, well within the washing of the waves, they are robust and vigorous.

Not far below the line reached by the ordinary tides, especially in neighborhoods of streams, or estuaries where brackish water prevails, a bright fringe of green skirts the shore. This consists largely of the confervoid algæ, or silkweeds, whose fine, filamentous fronds sometimes grow in tufts so dense that they are matted at the base. But in close company with these also grow many others. Here we find *Enteromorpha intestinalis,* whose tubular, inflated fronds have given it its characteristic Latin name, and its sister plants, *E. clathrata* and *E. compressa.* Here, too, occasionally attached to larger algal forms or lying loose in drifted clumps, are the pretty locks of mermaid's hair, a blue-green seaweed with the curious scientific name of *Lyngbya majuscula;* and occurring in spreading patches are the minute threads of *Oscillaria* and *Spirulina,* strange, restless plants which under the microscope exhibit a ceaseless vibrating movement. Then we come to the water, where *Ulva* abounds.

Who has not heard of "sea lettuce"? Ulva, which almost universally goes by that name, is the commonest and best known of all the seaweeds. That this is so is not because of its greater abundance, for there are many others far greater in numbers if not in range, or because it is the largest of all green seaweeds, therefore the most conspicuous, but it is by virtue of its association with those bays and inlets of a type whereon mankind has always been wont to congregate. It is identified with nearly every seaport and harbor

in the world. The reason for this is plain. Its formless fronds, often measuring several feet in length and breadth, are as thin as a newspaper. Thus they present a considerable area to the action of the waves; and although they can withstand the tempered movements of sheltered waters, they could never endure the

ULVA; THE SEA LETTUCE.

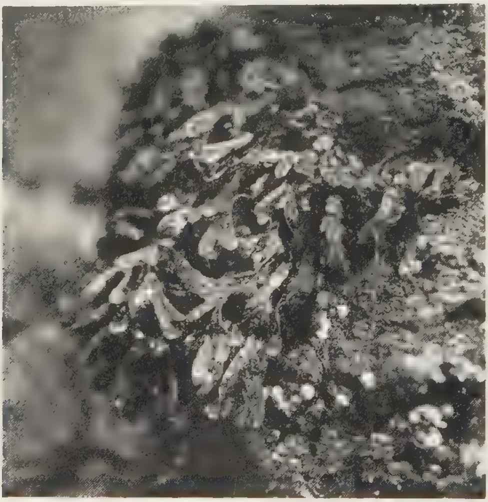
surging swells of the open coast. To say that Ulva is a beautiful seaweed would be to venture a praise more enthusiastic than critically just. Yet Ulva has its merits. Its broad, green, crispy fronds glisten like silk in the sunshine and forming as they do acres of veritable marine gardens they may well be included among the rarest of nature's lovely spectacles. And how the fishes love to sport among the lifting folds!

The sea lettuce is the common food of many creatures of the sea. Indeed the human species itself has not disdained to make it serve its needs. Under the name of "oyster green" this seaweed was once prepared for the table as a wholesome delicacy. But its value to the animals of the sea is twofold; besides serving as a source for food it gives off considerable oxygen in the water so that they may breathe. While all seaweeds give off more or less oxygen this property of Ulva is noteworthy and for that reason it makes a most desirable plant for aërating the indoor aquarium. It adapts itself readily to confinement and will thrive in situations that are fatal to other marine plants.

Next to Ulva, perhaps the most familiar seaweed is *Fucus*. Fucus, or the rockweed, is far different from Ulva, however, in color, form, and habitat. It is one of the brown seaweeds, although its color is more often an olive green, and grows in its greatest profusion between the tide marks on exposed rocky shores. The tough and leathery texture of this plant denotes its character. Holding fast with its suckerlike disk to the rocks of rugged shores, it breasts with impunity the shattering force of the driving surf. But its hardiness is exemplified not merely in the ability to live in a pounding sea; it thrives throughout the winter, and, under the scorching rays of the summer sun, during the fall of the daily tides, it survives temperatures that would shrivel the sea lettuce into a formless cinder.

In further contrast to the simplicity of green seaweed is its higher organization, or differentiation of parts. Some members of this genus have a distinct midrib. All the plants are forked and flat; that is,

they are expanded in one plane like an oak leaf. A distinctive feature, and one which marks quite an advance in the development of seaweeds, is its possession of air bladders and *conceptacles*, or spore chambers. The air vessels enable the somewhat thick and clumsy fronds to uplift themselves in the water and thereby



FUCUS, AN OLIVE-GREEN SEAWEED, GROWING ON A ROCK.

maintain a position most favorable for the assimilation of light and nourishment. When thus seen swaying in the depths, their beautiful bouquetlike forms bend to and fro with indescribable grace.

It is in the peculiarity of its spore chambers, however, that Fucus particularly solicits attention. For here we find the beginning of that complex process of

reproduction which is later to be found in such perfection among higher plants. In fact, this alga carries on its spore production in a way that is already as involved as the formation of seeds in flowering plants. The conceptacles are usually grouped at the extremities of the frond, and are easily identified, as their surface has a pimpled, or rough, appearance. Now Fucus is heterogamous; this means that the individual plant bears both the male and the female sex organs. The eggs and sperms are discharged in the water independently. The eggs float freely and without motion; but the sperms each possess two cilia arranged in a fore-and-aft manner, and these latter, being in a constant state of vibration, enable the organism to swim about. So small are these sperms that many hundreds can be contained in a drop of sea water. The eggs are considerably larger, though their details cannot be resolved without the aid of a good microscope. As the egg floats passively in the water, in some mysterious way—supposedly by chemical action—it attracts great numbers of male cells to it, and these arriving in such force, frequently set it to rotating by impinging against it. Yet of all the host that seek it, only one is favored. A fusion finally takes place, and the now fertile egg drifts around for a while, eventually finding a favorable lodging place on some rocky shore where it later develops into a new plant.

As Fucus must find a firm support to which to attach itself, it is obvious that its presence on the Atlantic coast would be relatively rare south of Long Island, for below this region great stretches of sandy beaches prevail. There does exist, however, in the deeper

waters off those shores, a brown seaweed closely related to Fucus, whose differentiated fronds, closely resembling the structure of higher plants, are often torn from their anchorage and found washed up on the beach. This is Sargassum, of which mention has been made before. Two plants of this genus, *S. vulgare* and *S. montagnei,* both of which measure less than three feet in length, are found as far north as Cape Cod; but a larger species, *S. bacciferum,* known as the "gulf-weed," grows off the shores of Florida. This latter seaweed has acquired considerable prominence from the fact that it composes the major portion of that extraordinary floating mass of vegetation circling about in the great sea eddies produced by the Atlantic currents and forming the so-called Sargasso Sea. After being carried far from their place of origin many of these plants continue to grow in this mid-ocean tangle as luxuriantly as on their native shores.

Many of the brown seaweeds are of economic importance. Particularly noteworthy in this respect are the giant laminarians of the Pacific coast commonly called sea wrack or kelp. Kelp is harvested by boats equipped with special machinery for the purpose. These ocean reapers bring in great barge loads of this free-for-the-collecting freight from where it floats in huge fields, and turn it over to industrial organizations which convert it into iodine, potassium chloride, and other by-products. Its high potassium content also allows it to be dried and used in that way as a soil fertilizer.

The large proportions of the kelps make them easily the fastest growing plants in the vegetable kingdom,

as they attain their full growth within a year. One of these is reported as having a stem of the thickness of a clothesline and reaching the length of nine hundred feet; along the greater part of this ropelike stem are attached numerous expansive "leaves." Another, the bladder wrack, has a stem the length of which measures a hundred and fifty feet. But, although its stem is relatively short, it is distinctive in having at the end a great globular float bearing leaflike appendages over twelve feet long.

Except for those low, invisible, fungous forms, the bacteria, marine vegetation is entirely restricted to the surface of the sea and its shallow waters. This limitation is obviously far short of that of the animals, who, as will be revealed in a later chapter, range to the greatest known depths. Now the reason for this restriction would not be hard to guess, even though our knowledge of conditions generally regulating the growth of plants on the sea floor were ever so imperfect. The chief factor, of course, is light; for the seaweeds are no more able than are their land relations to live beyond the reach of the sun's rays. The amount of light that penetrates the sea rapidly diminishes with increasing depth; therefore, few living plants are found much lower than a hundred and fifty feet.

Yet even at this level they do not sensibly decrease in numbers. They are, however, greatly reduced in size. Nor is this the only change. They are extensively altered in character. In fact, it is here in these remote regions, where filter feebly the last remaining rays of light, that flourish the most varied, the most colorful, the most exquisitely delicate and, in many

ways, the most beautiful forms of plant life. These are the red algæ.

Although red is their prevailing color, they exist in hues ranging from a delicate pink to deep purple, and these sundry shades, ordinarily the most pleasing of the spectrum, seem to acquire an unwonted beauty in the filmy or filamentous or ribbonlike structures of some of these seaweeds. Often a profuse branching occurs, and the plants resemble mosses or ferns. But such mosses, such ferns! Nature has no parallel, in any higher plant, for tint or texture. This red color, by the way, is only a mask. In spite of its predominance, there exists in these plants a large amount of *chlorophyll,* the green coloring matter that characterizes Ulva and the higher forms of vegetation, and that by some subtle alchemy converts the sunlight into plant food.

All red seaweeds are anchored forms. Moreover, as I have pointed out, they are particularly identified with the deepest waters in which algæ will grow. But it by no means follows that they are restricted to the deeper parts; they are, in truth, to be found living as high as the tide marks. The numbers and species, however, grow fewer as the higher levels are reached. This latter observation also may well be applied to their range as it extends northward; for they are essentially plants of temperate and tropical seas. In this connection mention of the corallines will not be out of place. This remarkable group of seaweeds, mostly displayed in the warm waters of tropical shores, secretes so great an abundance of lime in the cell walls that the plants become deeply incrusted and resemble

branching corals. It is on this account that they are called corallines. A representative type, though one which by no means attains the perfection and beauty of the tropical forms, is the common coralline (*C. officinalis*), found in tide pools and on rocks at low-water mark on New England shores and in Long Island

CORALLINA; A RED SEAWEED WHICH RESEMBLES CORAL.

Sound. Its rigid, jointed, and many-branched frond is often mistaken, by those unfamiliar with its real nature, for coral, to which it has some resemblance.

In the territory just mentioned, the amateur collector will also often find washed ashore many of the deeper forms, such as the brilliant *Griffithsia,* so named for an English algologist, *Ptilota* the feather weed, *Hypnea* the moss weed, and *Phyllophora* the leaf weed.

But he need not depend on the chance of the waves to start his acquaintance with this interesting group; an abundance of living forms will be found growing well within his reach. Of the genus *Polysiphonia* alone, there are over two hundred named species. If it so happens that he is fortunate enough to possess a microscope, some startling revelations await him in the examination of the structures of these threadlike plants. Under that instrument a filament becomes a bundle of filaments, or tubes, surrounding a central tube. These tubular parts are called siphons, and from them Polysiphonia (meaning "many tubes") gets its name. In some species the siphons are bare, and the filaments are banded with alternate rings of color. In others, a surrounding layer of corticating or bark cells cover the siphons, giving the filament an unmarked, uniform, but, nevertheless, attractive appearance.

Then there is *Ceramium,* the pitcher weed. This also shows to its best advantage under the microscope. Like Polysiphonia, it is banded, but its forked filaments are not made up of siphons. Another is *Callithamnion,* a soft, silky seaweed of cobweb fineness. This plant, too, is represented by many species; they grow in crimson tufts, and along each gauzy filament are dense dots of deep red.

However, the want of a microscope should not deter the ambitious beginner; a good, strong pocket lens will often serve him well. I shall add, moreover, that even the latter could be dispensed with, and there would still remain a numerous host whose obvious details would not fail to excite his wonder and delight.

Notwithstanding that the red seaweeds are found in

adverse situations, flourishing under the most unfavorable conditions known to chlorophyll-containing plants, they have, nevertheless, reached the highest development of all marine algæ. This is marked by their mode of reproduction. Now this is an extremely complex affair, and differs quite extensively in detail among the different members of the group. In fact, so involved, or modified, is it in some instances that it is as yet poorly understood, even by professed botanists. Still, I think that I can give some representation of the process as drawn from a very simple case, that will enable the reader to form at least a fair, if not complete, conception of its general nature.

Red algæ are peculiar and unlike other algæ from the fact that they produce no swimming spores. Their reproduction is carried out in two ways. These are termed *asexual* reproduction and *sexual* reproduction. In asexual reproduction, the spores are formed in an envelope which, with its contained products, is called a *sporangium.* Since the sporangium usually, but not invariably, carries four of these spores, they are termed *tetraspores.* These upon being discharged in the water settle to the bottom and immediately start to germinate and produce new plants. It will be noted here that this method is quite different from that prevailing in the spores of Fucus. There is no fusion of cells prior to the development of the plants. This is the usual way in which red algæ multiply.

But there sometimes occur in the life of a plant extraordinary circumstances, somewhat like the winter season or other unfavorable periods experienced by land plants; and these unfavorable conditions must be

bridged over in some way if the seaweed is to perpetuate itself. It accomplishes this through its most remarkable sexual reproduction. On a certain part of the frond it develops an organ called the *antheridium.* This gives rise to sperms which, like the tetraspores, are without cilia and are, therefore, unable to swim. However, instead of sinking to the bottom, they float about until they come into contact with another organ on the plant known as the *oögonium.* The oögonium is a bottle-shaped female organ with a long narrow neck. In the bulbous base is contained an egg. When the floating sperm reaches the oögonium it clings somewhere along this neck, and, perforating the wall at the point of adhesion, it passes its contents to the egg, thus fertilizing it.

Strangely, the immediate result of this fusion of the sex cells is not, as one would anticipate, the development of a new plant. Instead, the now fertile egg breaks up into numerous spores, and there appears in the place of the oögonium a fruitlike structure called the *cystocarp.* So what we have here is really a kind of sporangium or spore case containing asexual spores. But, unlike the tetraspores which cannot defer their development, these carpospores can await a favorable time or situation before proceeding to maturity; that is to say, before growing into a new generation of seaweeds. We find, then, in summing up the life history of the red alga, that beside having two modes of reproduction, asexual and sexual, they produce two sorts of *asexual* spores: The *tetraspores,* arising from a simple sporangium; and the *carpospores,* products of a fertilized egg developed within the cystocarp.

An acute observer once pointed out that there seems to prevail a natural rule to the effect that as an organ becomes more highly specialized or as plant and animal life becomes more advanced in development, the ability to regenerate injured tissues or lost parts becomes increasingly diminished. For instance, in higher animals the stomach, a primitive organ, can undergo considerable mutilation and recover its pristine vigor, but the slightest damage to the more specialized kidneys is practically irreparable. Then, again, the facility with which lower animals, from the sponges to the crustaceans, can grow lost parts, when compared with that of the vertebrates, is another case in point. Well, at any rate, whatever may be the value of this rule in its application to higher forms, it is certainly true so far as it is reflected by the seaweeds. With some doubtful exceptions, red algæ cannot give rise to new individuals if the fronds are detached from the base. In other and lower forms, however, growth constantly proceeds regardless of an injury of this sort. This method of cell reproduction, known as vegetative multiplication, is carried to an extreme by many green seaweeds. A good example is Ulva. When it is in the growing stage it can be torn into any number of parts, and each one will continue to enlarge into a conspicuous frond.

The seashore is the great evolutionary threshold of both plants and animals. I have already mentioned the fact that some of the marine algæ are learning to live out of the water; but there are, on the other hand, not a few land plants which have taken to the sea. And, curiously, these for the most part are represented by the higher, or flowering, forms. This reversion to

their ancient habits is not in any sense to be taken as a form of degeneracy; they have, on the contrary, acquired an uncommon degree of specialization in order to adapt themselves to an aquatic existence.

Like the seaweeds, these plants are intrinsically interesting, but they are especially noteworthy for their remarkable association with certain forms of animal

PRICKLY WORT; A FLOWERING PLANT OF THE SEASHORE.

life. Seldom do we find a bed of eelgrass (*Zostera*) without a host of hydroids, snails, and other creatures living among its watery glades; even one or two red algæ seem to prefer the slender leaves for their attachment rather than the rocks. The thatch (*Spartina*) and other plants of salt marshes and meadows are marked by some crustaceans as their very own. A species of fiddler crab (*Uca pugilator*) makes its home in such numbers in the muddy soil holding the thatch,

that it is rarely looked for elsewhere by experienced collectors.

Here I must conclude. It is not without a certain regret, however, that I do so. For, to me, there are few subjects more absorbing than that which forms this chapter. For the reader's proper understanding of that vast range of life which forms the groves and

SALT WORT; A FLOWERING PLANT OF THE SEASHORE.

gardens of the sea, I have necessarily been obliged to trace the briefest outline. But it would be a mistake for him to assume from this bare sketch that marine vegetation has no interest apart from what was occasionally pointed out. The plain truth is, there are periods in the life histories of various individual plants that are as dramatic and as charged with incident as those which arouse our emotions in the case of higher

animals. To grasp those situations, of course, requires a sympathetic attitude, an interpretative spirit fostered by affection. This, however, will not be slow in asserting itself. One cannot long associate oneself with them before learning that one has not to do merely with an inanimate, growing form, but with a very vital thing. And this, by the way, is just as true of the higher plants as of the seaweeds. It is a singular thing that of all our companions on this planet, the members of the plant kingdom are the most serviceable and yet the most neglected. Almost every variety of animal has been revealed to us through the fervent praises of distinguished pens. But where is there a Homer of the plants? Certainly, the answer is plain; and perhaps it contains the real reason why plants to the many always have been, and still are—just plants.

Chapter IX

FEATHERS AND FEELERS

THIS account of shore life would be incomplete if no consideration were given to that distinct and most interesting association of animals which occurs in connection with the jetsam deposited by the tidewaters. Therefore, I purpose to take the reader to one of those spots in my neighborhood in which my frequent presence has made me almost as familiar a part of the locality as the dune plants and beach grass that thrive in the sandy soil. The region whereof I speak is a narrow spit, some three fourths of a mile long by only a fraction of that in breadth, which almost completely bars the entrance to the marshy cove. This peninsular area is constantly changing in outline and topography, but in spite of the rapidly shifting ground, a prolific and numerous vegetation maintains its determined stand. Certain dune plants are trying hard to dominate; still, the strand is in no sense a typical dune. It is low-lying, and, with the exception of a sort of backbone, or central ridge, the tides nearly submerge it.

In addition to the great variety of shore life which crowds its tide pools and populates the sands, the isolated nature of the place, due partly to the wilderness of reeds flourishing in the slimy soil that connects it

with the mainland, and partly to the creek that separates it from the opposite shore, makes it particularly favored by the marsh hen and other birds—and by me. Here, more so than is possible at any other point along the harbor shore, I am able to install myself in some sequestered spot and follow also the actions of my humble friends of the sea, uninterrupted by the idly curious. Unfortunately, however, these advantages are growing less and less each year. The beach that lines the outer side of this barrier is the finest in the harbor. The bathers hereabout have discovered this, and every summer sees an increase in their numbers. On my own part, I have no selfish wish to see it otherwise; for who am I to put a personal convenience above the happiness of the many? Yet it is not without emotion that I regard the effect these seasonal incursions will have on the welfare of my pretty animals. Where are they going after being driven from their homes? No other place in this region offers such an ideal sanctuary. It is not large, but within its limits are contained a number of forms which, unable to thrive elsewhere, have sought it as the last remaining place of refuge. One of these, Limulus, the horseshoe crab, is, at best, fast becoming extinct; and it would be a pity to have this picturesque and inoffensive creature disappear from these shores entirely.

During July and August the heat of the sun beats down upon this strip of sand with tropical intensity. It is the season most loved by the animals of the sea and shore. At this time they are at the height of their activities. A walk along the water's edge reveals a teeming population. Many of them, alarmed at human

approach, strike out in all directions with panic-stricken haste. The scampering of the fiddler crabs making their way up the slope to their burrows and the progressive leaps of the minnow shoals are distinctly audible as a continuous, murmurous hum. Larger forms are also here displayed which do not take kindly to our presence. Almost under our feet the ebbing tide has left a molting lady crab. Partly buried in a puddle of silt, she fidgets uneasily, viewing us apprehensively with her twitching stalk eyes. Having been weakened by the profound physical change that she is undergoing, she was unable to swim out with the retreating water. But she need have no fear where we are concerned; far greater danger lies in the chance observation by some member of a flock of herring gulls now rising with a chorus of angry cries within a stone's throw of our advance. Nearing the spot where raged the recent tumult, we soon have no difficulty in learning why they resent our intrusion. High up on the beach is the stranded carcass of a fishing frog. The casting-up of these curious deep-water fish is not an uncommon occurrence on this shore; although in what manner they meet their death is not readily apparent. I once found a specimen nearly four feet long which had a mouth more than a foot and a half wide; it was intact, bearing no external evidence of any mortal injuries. Nor, on cutting it open to examine the contents of its stomach, was there anything to indicate an unseemly death. Sometimes fishes are known to die from the effects of trying to eat over-large spine-bearing creatures which they are unable either completely to swallow or to regurgitate. But the stomachs of those ani-

mals I have opened were generally filled to capacity only with herring or other small fishes in various stages of digestion—a circumstance, furthermore, which precludes the probability of death by sickness or starvation. For the reason that it is commonly supposed to allure

FOOTPRINTS OF A HERRING GULL.

its prey within reach of its great jaws by means of a dangling, baitlike organ at the end of a long modified spine on its snout, it is also variously called the sea angler or angler fish.

In the confusion of tracks around the carcass on the sand are to be seen those of other birds beside the herring gulls. One conspicuous footprint, with deep-

taloned indentations at the ends of the toe marks, shows that some wandering buzzard has stopped to eat. Another is that of the great saddleback gull, a bold, well-marked imprint, a perfect intaglio of the sole of the web-footed maker. The crow, too, has left its characteristic mark. But it needs no telltale footprints here to indicate that carrion is part of its common diet. Wherever this bird is found to congregate it leaves evidence of its food habits by the ejections from its mouth of long pellets of partially digested food. The seashore, however, is less plentifully dotted with these pellets during the summer than in the winter. Food is more plentiful inland in the warm months, therefore fewer crows are obliged to seek the beaches; moreover, at this time the pellets quickly crumble into pieces. Freezing weather causes them to retain their shape. As these cylindrical objects are sometimes as large around and over half as long as one's finger, they give an interesting clew to the extremely varied bill of fare of the animal. The seeds of sundry plants are common constituents, and often these are of a bittersweet, and even poisonous, variety; but in addition to these, there is apt to be present in considerable quantities the bones of fishes and of frogs or other small four-footed animals, the hard parts of crustaceans, shells of clams and mussels, periwinkles and numerous small mollusks, and not infrequently one comes across the wing cases of beetles and other portions of insect armor.

That the crow should become so integral a part of the shore life as is the gull, is not surprising. The opportunities this region offers to such an indiscrim-

inating palate are quite obvious. But what is it that attracts the other land birds which we see winging their way hither and yon over the burning sands? Here is the swallow; with its familiar headlong swoop it passes close over our heads. Here, also, is the ubiquitous sparrow, the robin, the meadow lark, the pipit, and the myrtle warbler, none of which is a carrion eater, or known to show a preference for sea food. Yet these, beside many other distinctly land forms, are as common to the seashore as they are to their native woods and fields.

The secret of their presence lies in their food habits. Most of them are insect eaters; and few places in the world are more prolific of insect life than that line of plant remains and other organic débris which marks the tidal heights.

While the scavenger work of the seashore is performed largely by beach fleas, the little amphipod crustaceans Orchestia and Talitrus, terrestrial animals having the same food habits, are vigorously disputing their province. The number of insect species is not large, but in numbers of individuals the proportions are enormous. Those actively engaged in reducing the jetsam are principally flesh flies (*Sarcophagus*), carrion beetles (*Necrophorus*), and Staphylinid beetles. Associated with these, however, is a tribe of parasitic and predatory prowlers whose important business it is to hold this prolific horde in check. Even worms—mostly Enchytræids—are represented here; and occasionally birds which are neither strictly scavengers nor eaters of flesh are to be seen picking over the heaps for tasteful tidbits.

Seating ourselves in the shade of a thatch clump, better to observe the industrious folk about us, our inactivity is almost immediately productive of fruitful results, but of a kind not exactly agreeable. With irritating persistency a large green-eyed fly attempts to settle upon some vulnerable part of our body. We make haste, however, to drive it away as soon as we

A STAPHYLINID, OR SCAVENGER BEETLE. THIS INSECT LIVES ON THE DECAYING MATTER AT THE HIGH-TIDE MARK.

recognize it. For it is *Tabanus costalis*, and its painful drill is something to be avoided. Notwithstanding that Tabanus is a true fly, or *Dipteron*, and is gifted with a powerful pair of wings that enables it to roam wherever it may list, this species is rarely found elsewhere than in the neighborhood of the sea. Its larval life is spent in the rich, muddy soil of salt marshes, where it feeds only on decaying plant remains. At this period

it is a simple semitransparent lethargic tube of liquid contents, and to see it thus is to witness a strange contrast to the splendid, tawny, emerald-eyed creature which it later becomes.

Look, there goes *Eristalis*, pursued by the robber fly

ROBBER FLY ATTACKING ITS PREY.

(*Erax rufibarbus*). Whatever advantages the first-named fly may have derived from its beelike disguise, the imposture surely does not stand it in good stead now; for the bloodthirsty assailant will as readily attack a genuine sting bearer as one which obviously is not. Other winged assassins pass. To flies, wasps, and beetles, there would seem no end.

Even the ground has its quota of killers. These are chiefly spiders whose nimbleness of foot gives them an additional advantage when seeking a hasty refuge in the tops of reeds or other shore plants at every incoming tide. There is, however, an air-breathing creature here among the ground dwellers that is submerged regularly—often for hours at a time—during the periods of high water. The insect so distinguished is the larva of the tiger beetle known to science as *Cicindela dorsalis.*

Now the grub of Cicindela is worthy of our attention. For the seashore naturalist, it has an especial interest in the fact of its being one of the very few insects of the shore which are not known to occur anywhere else; its individuality, though, would commend it to any one's consideration.

But where shall we look for this lethal larva? Not in the vegetal débris; its soft, unprotected body makes it too easy a prey for others thus to expose itself. The truth is, its only safe resort is in the ground. Its burrow is quite numerous, as is testified by small holes that perforate the surface, and is a vertical shaft some six inches deep with a fairly even diameter of the size of a slate pencil. This home Cicindela never leaves for a moment, until the time of its metamorphosis, when it emerges as a swift-flying beetle. How does it capture its food? Well, if our watch be persevering, we shall see an exhibition of its singular method.

In the meantime it is to be observed that the grub is nowhere in sight. This is due to its extreme timidity. So cautious is it that our slightest movement is sufficient to make it remain for some time in hiding. Presently,

however, our immobile vigilance is rewarded: the top of a flat, hideous head appears at the entrance of a burrow. It is hard to say which is the more striking about this glossy black countenance suddenly thrust into view, the formidable sicklelike jaws or the fixed pair of double-orbed eyes that glisten like tiny jet beads. These latter organs are so arranged that one part of the pair is pointed to the front and the other part to the rear, thus enabling the larva to see in all directions without moving its head. A few short bristles shine about the eyes and fringe the outlines of the face, enhancing the savage aspect of the larva. More than this is not observable at present. The creature remains within its shaft with its head blocking the entrance completely and in such a manner that it is on a level with the ledge. Indeed, as it now presents itself, it is not difficult to detect; but those stubby hairs are worn for no idle purpose, and I have seen them more often than not so encumbered with adhering grains of sand or other particles that to novice eyes the animal would readily pass as part of the surrounding soil. In this position it awaits its prey with a patience that would far outlast our own, did not chance bring an abrupt and early close to the monotonous affair.

A young isopod (*Idotea metallica*) about the size of an apple seed makes its way over the sand. On what business it is bent and where its destination may be is not clear, but its course lies almost directly over the larva's lair. The little crustacean does not differ greatly from its land relative, the common "sow bug" found under damp, decaying wood or under stones and in other dark, moist places, except that it is longer and

flatter and is covered with a coat of bright bluish green that shimmers with a metallic luster. It is a swimmer, but on dry land its mode of progression is virtually the same as its well-known cousin; that is to say, it moves at a fairly rapid pace. However, it does not move too fast for our Cicindela. When it gets barely within a quarter of an inch of that living trap, there is a blur, and with astonishing suddenness both the isopod and the grub vanish utterly from sight. Where they have disappeared is, of course, not hard to guess. Yet so quickly did the larva work that the eye has taken in little of what actually happened to the isopod or the extraordinary maneuver by which it was seized.

To establish this clearly, therefore, let us resort to a ruse. But as this is the last that will be seen to-day of this particular individual, it will be necessary to employ our wits at another burrow, of which there are plenty.

First a fly or some other small insect must be obtained. This is but a matter of a moment. A dead marsh miller lying near by suits the purpose exactly. Then, breaking off a dry reed, we fasten a fine thread at the tip. At the free end of the thread a noose is made and drawn around the fore body of the moth. The result, in short, is a miniature fishing pole and line baited and ready for use. Thus equipped, we establish ourselves at a likely spot and wait. Our subject soon appears at the top of a convenient hole, and with a cautious turn of the wrist the dangling corpse is lowered over the lurking larva's head. Snap! The swinging bait is struck so forcibly that the impact nearly tears it loose. The sharp-pointed pincers, however, close with

deadly precision on the body of the moth, and there is a strong, swift tug as the grub attempts to haul its prey down into the shaft. But this movement is checked by the thread; whereupon the animal, perceiving almost immediately that something unusual restrains its effort, loosens its hold and withdraws like a flash into its retreat; yet not too soon for us to take in certain details. The brief interval of time that the grub clings to the miller reveals the fact that when engaged in its operations it retains a firm grip on the walls of its shaft. Moreover, in so doing, it strikes with an upward thrust of its head accompanied by a sudden lengthening of its body which carries the fore parts and a portion of the abdomen well clear of the hole. This "jack-in-the-box" performance is accomplished, however, not so much by a telescoping of the body as would easily appear, but is largely achieved through its peculiar configuration. If our sight be keen enough it will have been evident that in retracting its body the grub, after a manner of speaking, doubled up on itself, by reason of the S-like shape in which it is roughly bent.

Now let us dig out the animal to see if anything more is to be learned on this score. Carefully removing the sand at one side of the shaft, we discover as we go deeper that the latter is of a uniform character and without any turns. Here we have a departure from the bore of most sand-dwelling beetles. Generally their gallery has a sharp curve that becomes horizontal near the top. The advantage that that construction offers in keeping the loose, dry, shifting sand from filling up the burrows is obvious. Nevertheless, our Cicindela well knows what it is about in sinking this simple shaft.

The nature of the ground indicates at once why a more complex burrow is unnecessary. In this instance the sand is always moist and more or less closely packed; therefore, its tendency to be blown about is reduced to a minimum. But what of the water? Although the grub need not provide against the hazards of the wind, it is clear that it must guard itself against the silting action of the waves. If we linger here long enough, the animal will show us how it overcomes this little difficulty. Still, as a considerable portion of our time has already been consumed in following its present behavior, it may be well to anticipate by explaining that it plugs up the entrance with sand just before the tide comes in. How it becomes aware of the time for approaching high water is a mystery. Yet this performance is as periodic as the flood. Within the space of an hour or more preceding every rise, it seals its hole as regularly as though it watched a tidal clock.

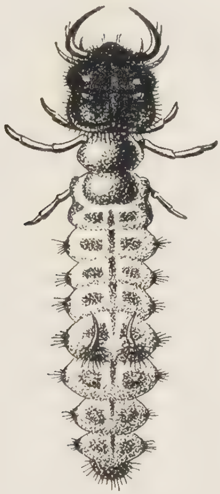
The question here arises as to how the larva overcomes being drowned in its narrow cell. This is answered in our examination of the burrow itself. As we dig into the porous sand, a noticeable difference is apparent in the texture of that portion forming the wall. Instead of falling away loosely like the neighboring material, the grains that surround the shaft come apart in clumps. This means that they are bound together with a sort of cement. Closer inspection with a glass does, in fact, show this to be the case; furthermore, the adhering particles are fixed in a way that makes the burrow practically water-tight, but admitting the penetration of air; the latter feature being of a decided advantage to the animal in its long winter sleep. It is

patent, therefore, that the periodic plugging of the entrance serves not merely to keep the drifting sand out when inundation occurs, but at the same time also to keep in the necessary oxygen to breathe.

When the larva is turned up at the bottom of the burrow, it proves to be a quite abject and helpless individual. Its length is not more than an inch; and as it attempts to escape its efforts may best be described as a fast crawl rather than a run, for its legs seem to be set somewhat closely together under its short thorax, and as it moves over the ground it is obliged to trail along a cumbersome hind body. The hard armor that encases its head extends over the greater part of the fore body, but the abdomen is soft and vulnerable, and its pale waxlike hue is relieved by markings on the upper part of each segment, making a triple row extending along the back. The segments are seven in number. They are well defined, and from the sides of each projects a little clump of short bristles. But the most remarkable of the animal's appendages is to be found on the fifth segment. This part of its anatomy is slightly enlarged, and viewed from the side a pronounced hump occurs, accentuating the already crooked curves of the creature's body. At the peak of this hump—that is, on the highest point of the back—two stout, sharp hooks, one sixteenth of an inch long, are set with their points turned upward. These are placed one on each side of the middle line that marks its length, and they in turn are encircled at the base with bristling hairs.

Although it may not strike one immediately that the bristles on the segments are used for climbing up and

down the shaft, one need not hesitate to decide the function of the hooks. In view of what we have already seen of the grub's habits, does not their position and appearance attest plainly that their purpose is for maintaining an anchorage in its hole when thrusting out



LARVA OF THE TIGER BEETLE.

its head to seize its prey? Furthermore, one can well imagine what would take place when it happens to catch a tartar, so to speak, if some device did not prevent it from being dragged from its retreat.

This is all that the little larva of Cicindela has to show us for the present. If we wish to inquire further into its history, it will be necessary to raise it in the laboratory where under controlled conditions the prog-

ress of events can be watched with closer attention than is possible in the open. There subsequent details, together with what can be learned from the adult in its natural environment, will give a complete life history something like this: The adult female tiger beetle, who is provided with a strong egg-laying drill, bores a hole in the soil with this instrument and lays a single egg. She is easily distinguished from the male, for the latter has the sixth segment broadly notched underneath so as to expose the seventh segment, which is invisible in the female; moreover, the first three tarsal joints on his front legs are very broad and bear a heavy coat of down on the under side. The female punctures the packed sand about fifty times, leaving an egg at the bottom of every hole. Two or three weeks later a grub hatches, and the little pit dug by the mother is ample enough to hold it; but as it grows, it enlarges its home, all the time going deeper and continually consolidating the walls. Its growth, of course, is like that of all other insects, a process which is closely bound up with the molting, or shedding of the skin. When this event is about to occur, the larva seals the entrance to its shaft, and goes to the bottom, remaining there until the change has taken place. For three years its life is spent in the ground. Throughout each winter it hibernates, closing its shaft for this purpose in the early autumn; it does not reopen it again until the middle of the following spring. Very shortly after its third and last disappearance, however, it changes to the pupal form. But this chrysalis stage, during which it retains its hooks and develops leglike processes from the four segments in front of them, to keep it out of contact with

the walls of its cell, is of brief duration. In the same autumn that it closes its door for the last time, it makes a complete transformation from a groveling grub to a perfect beetle. But the now winged tiger, instead of emerging at once from its lair, goes into a long winter sleep, and does not awaken until the warm and balmy air of May arouses it from its lethargy; whereupon it digs its way through the sand that blocks the shaft, finding itself finally at the surface. Here it proceeds to clean itself. As it rids its feelers and other appendages of particles of clinging dirt, the metallic sheen of its armor becomes resplendent. Its body underneath and over the head and thorax is a deep bronze green. Its elytra are mottled with blotches of creamy buff; and it occasionally lifts them to give its wings a flick in the genial sunshine. Like the larva, it has a pair of terrible jaws. In repose they are crossed; and, as the inner edge of each sickle is provided with several strong, sharp teeth, it is easy to see with what deadly efficiency the tiger beetle can work. The possession of this weapon gives it a sort of courageous confidence even in respect to humans; for if it be flushed it will run for a short distance and then fly just out of reach to face boldly the pursuer upon alighting.

We will here leave Cicindela engaged in its operations preliminary to taking its maiden flight. To follow it farther would be to witness a life of further slaughter, but add nothing essentially of interest therein—unless, perhaps, it be that it is double brooded and also hibernates in the perfect or adult stage: probabilities which are founded on more than a mere suspicion, but which are not known to be certainly true.

CICINDELA; THE TIGER BEETLE.

Still, notwithstanding the murderous instinct that makes the behavior of this animal not altogether a pleasant feature of its life, it constitutes itself by the very nature of that instinct one of our best friends; for in preying on other creatures it kills off scores of insects which are injurious to us in many ways.

PART TWO

THE TIDE POOL

Chapter X

FLOWERLIKE FORMS AND FANTASIES

From out of the past comes a memory of a wonder world. I am standing at the edge of a pool on a sunlit shore whose dank, glistening sands bespeak the outward running of a recent tide. The day is young. Shortening shadows of strange plant growths lie blue-black and sharp on a watery floor; the air is still and cool; the only sound is a faint murmur rising from the distant washing of a gentle surf. A feeling of bewilderment possesses me. The glassy surface of the tide pool, reflecting the brilliant azure of the sky, smites the eye with a violent glare, but in the transparent fulgor, fantastic forms present themselves to my startled gaze. I see a forest of fairy trees, fernlike glades of shimmering green, and a garden graced with filmy fronds of a delicate pink. Moving shapes I see, some without color and, so it seems, without substance; but many shine resplendent from mystic grottoes, or glide about like glittering jewels of living light. . . . Yes, form, color, and weight are here; though to my enchanted vision all realities become ethereal—the loveliness, the transcendent beauty of the scene is overwhelming. And as I look into the mysterious depths of this magic mirror, all about me has the semblance of a dream. . . .

Such was the impression produced by my first acquaintance with a tide pool. At the time of this experience, nothing whatever was known to me of the nature or the identity of the various plants and animals which inhabit the seashore. My interest in nature, always keen, had hitherto been excited only by such of its aspects as are ordinarily familiar to the inland dweller. It is true that those contacts were fraught with an undeniable charm. Many a ravishing hour had I spent watching some woodland watercourse with its divers wonders; indeed, I have often been beguiled into lingering at the margin of some glistening pond to watch with awe just the merest living mote. But on none of those occasions did my emotions respond to the degree that they did on my introduction to the tide pool. Perhaps this was because they had always been among the common things of life. It was not so much that marvels did not occur as that it did not occur to me to marvel. Alpine villagers, it is said, fail to find the same beauties in their region that move the tourist to such superlative expressions of delight. The ever-present spectacle of those lofty altitudes is unimpressive and without novelty, if not without charm, to a people born and reared amidst sublime surroundings. My own feelings and attitude in regard to the outstanding features of my terrestrial haunts were, doubtless, of a sort like this. Then for the first time I saw the sublime aspect of nature as it exists only in the sea. I was like one lost in a delectable land of illusion. But there was no illusion: I had acquired a newer vision; and from that moment I have never looked upon living things in

quite the same light as I had been prone to look upon them before. . . .

A later and closer acquaintanceship with things marine, naturally, has dissolved much that was mysterious to me on my initial meeting; nevertheless, this fuller familiarity has in no wise tended to diminish their earlier charms. Seldom do I venture along the shore without encountering some feature, not necessarily novel or strange, yet sufficiently impressive to awaken a responsive thrill. It must be confessed, however, that the waters of tide pools are more fertile of interest and incident in this respect than any other region of the shore.

As Harbor Beach is graced with a large and particularly attractive example of one of these natural marine aquaria, needless to say it surrenders to me many secrets of the sea. In the shallow water of this expansive basin (it is two or more acres) are often found, congregating throughout their proper seasons, representatives of nearly every type of life peculiar to these latitudes. Here are found the forms that line the high-water mark as well as those which range the deeper levels. For not infrequently is some strange straggler from the outer reaches caught unawares and left imprisoned by the retreating tide, unable to escape until the next succeeding flood. Sponges, too, swept in from darker and cooler depths, continue to grow without perceptible restraint in the genial currents of their newer habitat.

Such a one is the finger sponge (*Chalinopsilla oculata*), a dull orange-red individual with compressed fingerlike branches that look like lobes of melting

copper. And then there is its paler cousin (*C. arbuscula*), standing about six inches high, whose delicate and finer textured branches of tawny gray grow more slender but in greater profusion. Some sponges resemble crumbs of bread; others spread themselves in irregular golden masses over the fronds of seaweeds or the surfaces of stones. These latter generally first find their way here as fragments. Soon or late, however, some of these fragments drift into contact and coalesce, forming a single but larger and perfect unit. Still, of all the immigrants, the boring sponge (*Cliona sulphurea*) has the most striking habits. It is a light cream yellow in color and usually grows on the dead shells of the oyster and hard clam, though it sometimes settles on living shells to the great irritation of the animal within. It honeycombs these shells with galleries by absorption, wherein it establishes itself, showing only its wartlike prominences through little perforations about one eighth of an inch in diameter that riddle the surface of the valves. In time the dead shell is completely disintegrated by the work of this persistent borer, but the living mollusk, although hard put to prevent this disaster to itself, manages to delay if not effectually resist these encroachments by the constant secretion of new lime over the parts that are penetrated by the sponge.

But the sponge population of the tide pool is by no means composed entirely of immigrants. A community long established herein also holds its own. The brilliant orange-red incrusting sponge (*Microciona prolifera*), spreading itself in a velvety, tangled mass over shells and stones, is a conspicuous example. Less color-

ful but equally diverting is the lovely little urn sponge (*Grantia ciliata*). This is a particularly favorable type in which to observe the way in which all these animals work. If a specimen be placed in a dish of sea water, to which a trace of carmine is added, it will be seen that the coloring matter held in suspension is

TUBE SPONGE. A NON-CALCAREOUS SPONGE.

sucked through the sievelike pores on the creature's sides and expelled in a steady stream through the large opening that punctures the top.

I have referred to the sponges as animals; for that in truth is what they are. Aristotle was the first to find this out. So, you see, I am not setting forth a fact that is particularly new. Yet, in spite of the age-old knowledge of their identity, there is a prevailing impression

that sponges are plants. This misconception no doubt arises from the appearance of those which are in commercial use. Such sponges, however, are only the horny skeletons which in the living animals were completely covered with a soft tissue of cells. Even in life, they are by no means typical of the group in general. For sponges are not only extremely variable in size and color; they are also found to grow in a vast variety of forms. Some species are so small that they are scarcely visible to the naked eye; others grow to such proportions that their dimensions are only to be measured in feet. Again, they range from masses so indefinite in outline as to appear like monstrous aberrations, to symmetrical structures of exquisite shapeliness. Nevertheless, the fibrous framework (spongin) of the common commercial sponge identifies it as belonging to the *Non-Calcarea,* one of the three classes into which all of these animals are divided. The skeleton of those sponges belonging to the *Calcarea* differ in being composed of mineral spicules (lime) or a combination of lime and spongin. This flinty material gives these individuals a hard and rigid character. It should be noted, however, that among the calcareous sponges some odd examples exist whose skeletons consist wholly or nearly so of particles of sand.

Although the sponges are undoubtedly animals, they are very low ones. Indeed, they stand near the foot of the ladder that symbolizes the evolution of the many-celled organisms. There are many other animals which are still lower, but they consist of a single cell. The sponges, however, are only a step higher, for, although their bodies are composed of an aggrega-

tion of cells, they have not so far progressed as to acquire a stomach or anything resembling the specialized organs that distinguish other multicellular creatures. It is on account of their low organization that they may be cut into pieces without killing the individual, for each piece will continue to live and grow; by the same token, certain members of the same species are enabled to coalesce when coming into contact.

As all animals must eat in order to live and grow, the individual sponge, notwithstanding its having no mouth or stomach, manages this important business in a very efficient way. And although utterly incapable of locomotion, it captures its food in a manner no less adroit than that of the most active swimmer. To arrive at an understanding of how this is done, let us look more closely into its structure.

In the living animal, the organic parts—that is, those parts which do not comprise the framework—are made up of a soft jellylike tissue consisting of three different layers of cells. The outside layer, which is virtually the skin, is composed of flat cells, and is called the *ectoderm*. The middle layer, known as the *mesoderm,* makes up the main mass of the body, and it is the function of these cells, which are of various shapes and kinds, to form the framework and take part in the reproduction and digestion. The internal layer, or *endoderm,* is an arrangement of cylindrical cells, each one of which has at its exposed end a cup, or collar, that encircles the base of a freely lashing flagellate hair. Now these thread cells (*choanocytes*), so-called, literally line the walls of the many locks, or chambers, in the canal system that traverses the sponge, and it is they

that capture the minute plants and animals which pass in through the pores with the circulating water. But please understand—it is not the cilia, or hairs, that catch the food; *their* office is merely to create the currents which keep the water moving, a condition maintained by their constant vibration; they both take in their food and eject the waste products of digestion through the circular orifice within the collar. Thus, in fine, the sponge works something like this: Through the innumerable fine pores that cover the outside of the animal, the water is strained of its coarser particles of floating food and the finer material is carried through incurrent canals into ciliated sacs or chambers, the cells of which select and absorb the suitable ingredients; thence the streaming atoms are diverted into the large channels and pass out through craterlike vents called *oscula*. In proportion to the pores, the oscula are few in number; in fact, it is due to the porous structure of sponges that they have received the scientific name *Porifera*.

The sponges are singular in having no natural enemies—unless we humans in our commercial exploitations of these animals can be included in this category. But even here our attention is confined only to the genus *Spongia;* and we make some effort to compensate for their reduction by artificial propagation. Living sponges are cut into pieces, and these are planted in the most suitable situations favoring their growth. They grow rapidly, attaining a marketable size within a year. The commercial sponges of this hemisphere are all taken from Florida waters, and off the shores of the Bahamas and the West Indies in depths of less than

thirty feet. The finest sponges in the world are those from the fisheries of the Mediterranean and the Red seas.

Natural reproduction in these creatures is carried on in two ways. In the sexual method, which is the most common, eggs and sperms are formed in the mesoderm. The fertilized eggs escape as rounded ciliated larvæ which, on finding a favorable bottom, immediately attach themselves; given to growing rapidly, they soon become mature individuals. Sponges reproduce asexually by budding. The buds in some instances remain attached to the parent and continue to grow; usually, however, they drop off and drift away to begin life anew.

In another chapter we have seen that certain seaweeds, the corallines, bear a close resemblance to the corals; there are, on the other hand, animals which have every appearance of being seaweeds. Their plantlike character is even more marked than that of the sponges. These are the fixed *hydroids;* and although the ordinary eye would never associate them with jellyfishes, their relationship, as a matter of fact, is not far removed, for they belong to the cœlenterates, or polyps. Indeed, all the animals which are now known as cœlenterates were at one time called *zoöphytes,* a term meaning "animal plants," and suggested by their likeness to plant forms. And it is the class *Hydrozoa* of the cœlenterates in which are included all the hydroids, both fixed and free-floating.

The fixed hydroids differ from the free-floating forms in that they are invariably colonies of associated animals which remain attached to a common base

throughout their communal life. That is to say, like plants they spend their entire adult life on the spot where they originally started to grow. It is true, in this respect they do not differ from the sponges, but so much more pronounced is their plantlike appearance that the comparison here is quite to the point. Some there are which liberate swimming bells. It is for this reason that hydroids often have been called the nurses of jellyfishes.

Throughout the summer months the fixed hydroids are well represented in my tide pool. However, of the four main groups, or genera, into which these animals are divided, *tubularians, campanularians, sertularians,* and *plumularians,* the sertularians are the most abundant. Hanging like frosted fringes from the fronds of seaweeds, can be seen the silver sertularian (*Sertularia argentea*); and the sea cypress (*S. cupressina*), a species somewhat similar, with its arched and drooping branches, forms funereal groves over shells and stones; but the commonest and in one sense the most curious is the creeping sea oak (*S. pumilla*). This hydroid crisscrosses its silken stems in such profusion that it sometimes hides completely the rocks or seaweeds on which it grows. From the tangled web, there rise at close intervals slender, upright stalks about an inch in height adorned with zigzag branches.

But how is one to determine their animal nature and avoid confusing them with seaweeds, which they so obviously simulate? Very easily. A strong glass, however, must be used for the purpose. All hydroids, in fact, can be studied to advantage only under the lens. Few sertularians, as a rule, reach higher than a foot,

and their branches are so fine as sometimes to be almost invisible. When magnified, a branch will be found to consist of a horny shell or tube divided into more or less regular internodes. In some species this tubular branch contains a single canal throughout its length; in others, it may contain several. These canals contain living substance, the horny exterior being only a support and protection. But the most striking thing that greets the eye are the flowerlike forms arranged alternately along opposite sides of the internodes, and which constitute the individual animals themselves. Each one is an anemonelike creature—in this case, called the *hydranth*—held in a transparent cup of amber, over the brim of which it spreads a spray of sixteen tentacles, silvery petallike processes of gossamer fineness. These are arranged in a single whorl around a conical, or dome-shaped, proboscis having in its center a tiny aperture, the mouth. The cup that holds the hydranth is known as the *hydrotheca,* and in sertularians this is almost always set close to its supporting branch without a connecting stem, or pedicel. On the hydrothecal rim is a hinged structure which works like a trapdoor when the hydranth retracts, closing after the animal to protect it from harm. A diaphragm forms the floor of the cup, and through a hole in this passes part of the body of the hydranth, making it continuous with the other hundreds of hydranths which compose the colony.

At occasional points along the branches, larger urn-shaped bodies are to be seen. These are the reproductive organs (*gonosomes*), and with rare exceptions the entire colony will contain sex organs of one kind only—which is to say, the colony is either male or

female. In sertularians, sexual reproduction is a process not greatly unlike what we have observed in the case of the seaweeds. The sperm cells stream forth into the water in countless numbers. On reaching the female colonies, they pass through a perforation in the top of the gonangia, seeking the eggs. Only a few are fortunate in finding the ova, however, whereupon fertilization is immediately effected, to be followed later by the development of the embryos. Eventually these embryos grow into ciliated larvæ which, on being liberated, swim to some substantial support and proceed forthwith to start new colonies.

The campanularian hydroids, to which reference has been made, are many of them similar in naked-eye aspect to the sertularians. But they differ quite noticeably under the glass. Take Clytea (*Clytea poterium*) for example. What in most sertularians is a horny cup set close to the branch on which it is borne, is in the case of this animal a stemmed goblet of crystal transparency. The goblet, bell-shaped and open at the top, is smooth around the rim and without the angularities or modulations commonly found in campanularian hydrothecæ; but the stem is faintly ringed throughout its length, giving the merest suggestion of an ornamental pattern—in short, the simplicity of its design makes it a fitting support to so chaste a chalice. The hydranth —but how shall I describe the hydranth? Every goblet contains a cluster of scintillant tentacles; yet so feeble is the light they reflect that they look like the pale glowings of ghostly stars. Somewhat like the sertularian, the sea oak, this hydroid is a creeping form. The main stem runs rootlike over the stones or seaweed to

which it is attached, and this gives rise to the upright pedicels bearing the nutritive and the reproductive organs, or zooids. In Obelia (*Obelia commissuralis*), however, a campanularian generally found in company with Clytia, the form of growth differs considerably. Here the main stem rises to a height of six inches; it carries branches spirally arranged around its axis, and these in turn subdivide into other and shorter members. The ultimate branches are in reality the ringed pedicels of twelve-sided cups. The cups are bell-shaped but slightly incurved. Indeed, the campanularians get their name from the characteristic shape of the hydrotheca, for *campanula,* from which the name is derived, is literally "a little bell." The reproductive zooids, larger and vaselike, are on short, ringed pedicels occupying the angles of the branches.

Now, although the campanularians just described have a superficial resemblance, even under the glass, to the sertularians, it is here in their outward aspect that their similarity ceases. Their life histories are totally different. In the life cycle of these hydroids is exhibited that peculiar phenomenon known as alternation of generation (*metagenesis*), two different forms of individuals in one species, or, to put it another way, one kind of individual in two separate and distinct forms. Specifically, Clytia and Obelia are at one stage of their lives fixed hydroids, or polyps; at another, jellyfishes.

Here is how it comes about. The reproductive zooids of these animals, unlike those of the sertularians, produce neither eggs nor sperms; instead, they contain little stacks of saucer-shaped medusæ, or jellyfishes, which, in their form of attachment to one another by

the middle of the convex side, recalls what we have observed in another place regarding the strobila of the large jellyfishes. When, at maturity, the cover of the zooid ruptures, the tiny jellyfishes are liberated. From the inside center of a swimming bell thus set free depends the stomach of the creature, having at its outer end a four-cornered mouth. Diverging from the point where the stomach is attached are four tubular canals in the bell which are continuous with a circular canal running around the rim. This is usually a conspicuous feature, and often serves as an aid to identification.

When a hydroid is in the jellyfish stage, it may be said to have reached the highest point in its development; for it is only in the mature medusa that sexual reproduction occurs. The eggs are pear-shaped ciliated bodies, which are dispersed by the parent medusæ at the end of summer; they swim or drift around until they reach a favorable anchorage; whereupon they grow into hydroid colonies which in turn give rise to other jellyfishes in the following spring. Some medusæ, in addition to their egg-bearing capacity, can reproduce by budding, producing smaller individuals on the stomach or on the rim of the bell. Moreover, not all campanularians are positively known to be of the above described type. Many of these hydroids have not yet been observed to bear medusa cups; nor can all the undoubted hydroid medusæ be identified with the polyp colonies from whence they came. What is more, some live always in the medusa state, having no colonial existence whatever.

The plumularians, as the name would indicate, are featherlike hydroids—at least they were when this

name was first applied. But now, since our knowledge of these animals has been vastly extended, a quite numerous group of individuals has been included among them which have no resemblance to a feather. For instance, there is one (*Antennularia antennina*) which often appears in my tide pool, that is decidedly weedlike; it grows in dense clusters of sparsely branched upright stems to a height of eight or more inches, and is by no means prepossessing. However, among those forms which do bear out their characteristic name, are the most beautiful of all fixed hydroids. Such is the sea plume (*Aglaophemia struthioides*), a species found on the Pacific coast. It has a striking likeness to a miniature ostrich plume, and the rich, colorful tones of some individuals make them even more attractive than the object for which they are named. This hydroid, like many other plumularians, has the zooid cups arranged only on one side of their supporting branch. The cups are without pedicels, or stems.

But there is one thing in which plumularians agree, and it is the distinctive feature that now identifies all members of the group regardless of their superficial aspects. This is their stinging organs known as *nematophores*. Whereas, in the other fixed hydroids that we have considered, the tentacles of the hydranth are the only organs bearing stinging cells, in these creatures the nematophores are additional members invested with these deadly darts. These are bodies of sundry shapes, the external shell being generally tubular or trumpet-shaped, containing a single tentacular finger capable of great extension. They are variously situated along the internodes and sometimes on the sides of the

zooid cups themselves, compared with which they are greatly inferior. Their purpose is not definitely known, but on occasion they can function as weapons either of capture or of defense. It is supposed, however, by many naturalists, that the nematophores are merely degenerate zooids. Reproduction is of the same type as that of the sertularians; there is no medusa stage. In the genus *Antennularia,* however, exists the unusual instance of both male and female zooids in a single colony.

In a well-shaded spot at the edge of the tide pool, where the overhanging mud bank exposes the mussel-laden roots of the thatch, I often find a hydroid which is incomparably more like a flowering plant than any other species of my acquaintance. Not only does this apply to the polyps, but the colony as a whole has every appearance of a floral bouquet. It grows on the shells of the mussels, yet not infrequently it attaches itself to the dead stems and roots that are imbedded in the side of the bank. Quite dense are its clusters, and fully two inches high; and its amber-tinted stems are terminated by the prettiest of pink hydranths. It is one of the tubularians (*Thamnocnidia spectabilis*), and so like a certain real plant is it, with its delicate stalks and starry zooids, that it is known everywhere as the passion flower of the sea.

I think it hardly necessary to point out here that the flowerlike zooids, as is the case with other hydroids, are the nutritive parts, and that their stinging properties, besides assisting in the capture of small organisms, are of considerable help in the animal's defense. But, let me say, this pretty polyp, powerful as it is in its way,

has, nevertheless, some irresistible enemies. On one occasion I observed a roving herd of fiddler crabs descend into the water of the pool and strip these diminutive gardens bare of every branch and blossom. But their greatest foe in this place undoubtedly is the hermit crab; when this hungry prowler finds them out he will

CLAVA; A COLONY OF TUBULARIAN HYDROIDS. (ENLARGED.)

spend hours in plucking off the clusters—plucking off many more, in fact, than he can possibly consume.

Now in regard to the hermit crab and its appetite, an odd sight sometimes presents itself. Often one of these creatures will be seen searching assiduously for food while the shell which it bears is literally covered with living hydroids. Yet, though its craving may be ever so keen, it will not touch them. These hydroids, too, are tubularians, and are generally of the genus

Hydractinia. They form a soft mosslike covering, usually of a whitish or pinkish color—the lighter-hued colonies being male, and the darker-hued, female—and are very seldom found growing elsewhere than on the shells of hermit crabs. Here, then, we find that re-

HYDRACTINIA; A COLONY OF TUBULARIAN HYDROIDS. (PHOTOGRAPH MADE OF THE LIVING ANIMALS GROWING ON A SHELL OCCUPIED BY A HERMIT CRAB; GREATLY ENLARGED.)

markable instance known as *commensalism,* a term which, freely defined, means "dining at the same table." But in this case, as indeed is the case with most true commensal animals, they do more than merely dine together; they really render each other a service. That is to say, this sort of association is formed for mutual benefit. The tubularians, beside the concealment they

may offer to the crab, are effective against its enemies with their stinging weapons of defense. The hermit crab reciprocates by carrying the colony about to places most likely to be plentiful with food; a favor enhanced by the fact that the polyps are also assured of better oxygenation.

When a colony of Hydractinia is examined closely, the individual polyps will be found to rise from a horny, rootlike network creeping over the surface of the shell. It will further be observed that the zooids are of three entirely different kinds: a nutritive member carrying a crown of tentacles; a second slender individual without tentacles but well armed with stinging cells, and a shorter stalk on which a small cluster of ovoid bodies is attached near the top. These latter are the gonophores. Hydractinia has no jellyfish stage; the eggs develop into swimming larvæ which seek the shell of some other hermit crab than that on which they were born, and there commence another colony.

The characteristic feature that distinguishes tubularians from other hydroids is in their long slender zooid-bearing stems. These in some instances reach a length of ten or more inches; often they are branched. The zooids ordinarily have two rings of tentacles encircling the mouth. In many species, however, the mouth is raised on a prominence, or proboscis; and not infrequently reproductive zooids will be attached between the two rows of tentacles or just below the outer fringe. In no tubularian does a horny hydrotheca cover the hydranth.

Such free-swimming colonies of hydroids as this pool affords are few if not relatively rare. This is not to

imply that there exists a scarcity of these forms. They are, on the contrary, very numerous. Their usual haunts, however, are the more open spaces of the sea. Southern and tropical waters, particularly, are prolific of these wandering creatures. Once in a while some of these warm-water dwellers drift to these northern latitudes with the Gulf Stream, eventually finding their way to this shore. Of these floating wanderers, one form is especially worthy of our attention here, because of all the free-swimming hydroids it is the most beautiful and the most famous—and the most dangerous.

Physalia arethusa, or Portuguese man-of-war, as this notorious cœlenterate is called, floats on the surface of the water—a resplendent, fairy craft of faint purple and rose. The hull, or body, of this marvelous ship is a bubblelike bag about five inches long roughly resembling a dirigible balloon; and it carries a crest, or sail, that can be raised or lowered before the wind. The bag is filled with air, and from beneath trails a cluster of brilliant blue streamers which sometimes are nearly one hundred feet in length. In addition, there depends a mass of flask-shaped bodies, or feeding zooids, and some that look like miniature bunches of grapes, the reproductive zooids.

The attractive tentacles of Physalia, as in the case of the large jellyfishes, are covered with stinging cells; but in this instance they are more poisonous and paralyzing. A strange thing—is it not?—that such an exquisite creature should possess so terrible a power. No fish of ordinary size can escape when coming in contact with this alluring snare. In its deceptive mazes sea turtles weighing twenty pounds or more are, in spite

of their scaly armor and leathery hide, caught and benumbed and rendered utterly helpless. Nay, the danger that lurks in that deadly touch makes the man-of-war a fearful animal to encounter by even the human swimmer.

Yet, notwithstanding the deadly nature of the tentacles, they harbor, unharmed, certain little fishes which swim throughout the treacherous toils with perfect freedom and unconcern. This, you will admit, is truly remarkable. How much more so, then, is the fact that these constant companions of Physalia are of the exact color—a bright, pretty blue—as that of the monstrous members among which they make their home!

Chapter XI

CAMOUFLAGE

In the color resemblance of the fishes that follow Physalia, we have touched upon a circumstance which leads us now to consider some important and fundamental advantages possessed by certain animals of the seashore in their struggle for existence. I refer to those aggressive and protective endowments, apart from distinct organs of offense and defense, which are usually known as mimicry, masking, deceptive coloration, or by some term of similar significance.

The dense population of the shore makes competition exceedingly keen. Everything that is edible has scores of hungry claimants; this applies to the larger living animals as well as to the most trifling bit of organic food. Now, as one half literally subsists on the other half, it is obvious that any device which will enable the possessors the better to obtain something to eat or to avoid being eaten, will promote the welfare of the species as effectively as that of the individual. No one can seriously study the conditions that prevail in this area without becoming early aware of the fact that, notwithstanding the enormous prolificacy which obtains here, the balance of life is maintained at a somewhat critical point. Even among the dominant

forms, the line that lies between their present supremacy and total extinction is by no means a broad one. Many mighty multitudes are holding their own in the tremendous struggle merely by virtue of some apparently insignificant feature in form or color.

Such advantageous features as swiftness of movement or unusual strength, of course, contribute largely to an animal's ability to make a living; but even these, in many instances, would be quite useless were it not within the power of the animal to render its presence unperceived when approaching its prey. In so doing it seeks to identify itself with its surroundings by one of three ways: by actual concealment, or hiding; by disguising its appearance with a covering of materials miscellaneous in origin—that is, by masking; or, as is most commonly the case, it relies on its natural color or markings or peculiar shape to keep it inconspicuous. Thus it will be seen that the resorts of the killers in deceiving their victims are as ingenious as they are varied. Human enterprise is hardly less distinguished. When, in the recent war, we went into the business of butchering each other, we took a hint from the animals, and, as our borrowed methods needed a distinctive name, the word "camouflage" came into popular use. Although science has not yet adopted this very useful term, its employment here will not be out of place.

Camouflage, then, may also serve the purpose of protection as well as aggression. It is clear, moreover, that the capacity of a creature to conceal itself from its enemies is of an importance not inferior to that of making itself invisible to its prey.

Fishes are classic examples of natural camouflage.

Their hues and markings almost invariably harmonize with their native haunts, and a great many species are capable of changing their colors momentarily to conform with the prevailing tints or tones of various localities. As nearly all of them are white along the under surface of the body, it is not unlikely that to their enemies which view them from below they would be confused with the light above; and to the birds and other enemies over them, their markings and coloration doubtless make their forms quite indistinct. In the perpetual darkness of the deep sea, camouflage is unnecessary. As a consequence, we find the fishes there unmarked, their entire bodies being an inky violet in color, below as well as above. In truth, to say nothing of the birds, such as slaty blue gulls and terns, which are colored like the sea, there are throughout every group of marine inhabitants—mollusks, crustaceans, echinoderms, worms, etc.—abundant instances wherein the perpetuation of the species is unquestionably due to protective or aggressive resemblances.

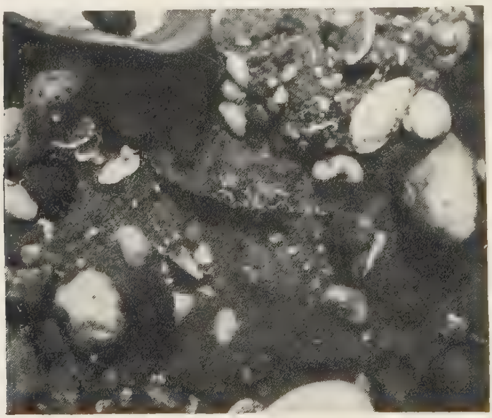
However, it is not my purpose to range the entire ocean for specific instances or to recite even a representative list of examples. Nor is it necessary. My present object will be fully attained, I think, without venturing beyond the comparatively narrow limits of my tide pool. At any rate, let us see what it holds for us.

This briny basin is so situated that when the tide is low its broadest expanse is separated from the waters of the harbor by a reef of gravel and sand. Owing to the shifting nature of this material, the outer shore of the pool is continually changing by the tidal action;

consequently, few plants find a footing here. And for a considerable area along the margin, the clear, shallow depths also appear quite barren of animal life—at least it would thus appear to the inexperienced. Save for a few small snails clustered in the furrows of the rippled floor or an occasional hermit crab cautiously roaming about, there would probably be little else to attract the notice of the average passer-by; yet unknown to him he would be the focus of many pairs of eyes belonging to creatures much larger than these. If he unsuspectingly steps into the water at this place, surprising evidence of this fact will manifest itself. Almost from under his feet will be a scurrying of shadowy forms slightly smaller than his hand, in length and breadth. Let him follow one of these creatures in its flight and determine exactly where it stops, and he will discover that he is utterly unable to locate it. So completely has it effaced itself from view that he begins to doubt his sense of seeing. With a hand net he may perhaps succeed in capturing one of these elusive shadows, but not so long as it is content to remain at rest on the bottom. It must first be startled from its place and then be caught on the leap, so to speak.

After which it will prove to be a fish; a flounder, in fact, or flatfish (*Pseudopleuronectes americanus*). A very unusual fish it is, also; and in more ways than would appear at firsthand. It swims and lies flat on one side, the lower side being white, or colorless, while the upper side is grained and mottled and presents an appearance identical with the coarse, sandy floor of its haunts. These imitative markings are not confined to the body alone; they extend over the fins and tail.

Here, in a word, is the real reason why the flatfish is indistinguishable when it is motionless. The most striking of its adaptative features, however, is the position of its eyes. In the common fishes familiar to everybody these organs, like those of the higher animals, are situated one on each side of a middle line dividing the right and left half of the body. But the



ROCK CRAB CONCEALING ITSELF IN THE SAND. THE ANIMAL IS IN THE CENTER OF THE PICTURE. THE FORE PART OF ITS BODY AND THE ENDS OF ITS CLAWS ARE THE ONLY PORTIONS EXPOSED.

flounder is almost a freak; its eyes are both on one side of its head; in other words, on that side of its body which it keeps uppermost. When one considers, moreover, that this creature is hatched as a transparent fish, swimming vertically in the water, with an eye on each side, the foregoing circumstances seem all the more striking. Nevertheless, it should be observed that these changes are not more marvelous than the

postembryonic metamorphoses by nearly all of the other animals of the sea. Indeed, I may add that the more metamorphosis is studied, the more it becomes divested of its aspect of marvel, though its absorbing interest, of course, never diminishes; for reduced to its simplest terms, metamorphosis is development. Those features which excite our wonder usually do so because of the extraordinary or strange contrasts they present; that is to say, development, always gradual and orderly in its course, is sometimes, however, revealed only as if it were an occasional occurrence, consequently giving the impression that its progress is marked by sudden transitions from one peculiar phase to another. As I have said, our flatfish swims vertically when hatched. Soon it starts to rest itself obliquely on the bottom, and the eye on the lower side commences to turn upward. As growth continues, this eye gradually moves with its socket around the forehead accompanied by a twisting of the skull until eventually both eyes and both sockets are more or less approximated on the upper side. By this time the fish has assumed its characteristic flat position. But the end is not yet. The full-grown flatfish is an inhabitant of the deeper and darker waters; it is only the young and immature animal which I find frequenting the shallow bottom of my tide pool. Therefore, before its growth will have been finally completed, it will have changed its bright sand-colored coat to one of a hue more somber and in keeping with the surroundings of its adult home.

Now the capacity for color resemblance that inheres in our flounder is clearly of a decided advantage. Were it not so endowed, it would become the prey of count-

less larger creatures; for it is a harmless and rather feeble swimmer, subsisting only on small mollusks, worms, and crustaceans, and its sole means of protection is by escaping observation. Notwithstanding its apparent immunity, it has several harassing enemies which make its existence anything but serene. Presently we shall have occasion to see one type of these killers at work.

The whole of the question of camouflage among animals is as yet imperfectly understood. It is known, certainly, that deceptive resemblance confers an enormous degree of protection to those forms so distinguished and which are too weak to resist their superiors. But what is the answer in regard to those which are equally defenseless and which by no stretch of the imagination can be considered inconspicuous? After eliminating those instances where inedibility, unusual prolificacy, agility, and kindred conditions may be factors, there yet remain cases in which the species seem to thrive without the apparent protection afforded the majority. These matters, doubtless, will some day be cleared up when our general knowledge of the conditions of life is more complete.

There has been much nonsense written on this subject. It has been seriously suggested that deceptive resemblance is an exercise of the will on the part of the animal; although it is only fair to add that no competent naturalist nowadays holds this to be the case. Nor should the learner who perchance has read some of the older overenthusiastic literature entertain this belief. In what way, for instance, the flatfish has come to acquire and exercise its remarkable property of de-

ception is even now not agreed on by naturalists, but not one of them asserts volition or intent to be a factor. That animals may adopt certain habits, and that these habits may tend to bring about actions in long-continued circumstances which accentuate or reënforce those deceptive features of form and color, is patent to any one who has a mind to study the matter; but that this is the result of reason, it does not at all follow. Rather, it is instinctive or reflex; and these inherent qualities are the result of slow and gradual growths through a long line of ancestors. And here too, by the way, is a broad hint regarding the colors of those creatures which do not seemingly find them useful. It is not improbable that the color markings of many present-day marine animals exist solely as the result of heredity; they were handed down by ancestors who, living under different conditions, found them directly and decidedly beneficial.

The objections that may be urged against volition in the case of color resemblance cannot be maintained in regard to that method of camouflage known as masking, except, perhaps, only insofar as instinct is concerned. Strangely, the most celebrated instance of this form of disguise is not, as one would expect, among the fishes, but is among the crustaceans, a group far less advanced in general intelligence. The crustaceans thus eminently distinguished are the long-legged spider crabs, a tribe of creatures so resourceful that they have often been honored with a place at the head of the entire group. When collecting seaweeds in my pool, I have several times come across the natives of this vicinity (*e.g. Libinia dubia, L. emarginata*) in a most unexpected manner. These animals have

evolved the habit of planting on their bristly backs all sorts of marine vegetation and low forms of animal life such as hydroids and sponges. The result is that they are sometimes so completely hidden by these growths that their presence is indistinguishable in normal situations. In gathering material, therefore, I have been deceived into attempts to appropriate the private property of these animals; and my efforts to detach some likely-looking specimen from its base brought a pair of puissant pincers to bear upon my hand. These crabs are sluggish in their movements, which perhaps accounts for their habit of disguising themselves, and although some individuals have legs that spread over a foot they succeed in masking their appearance very effectively.

The plants and other growths which they gather for masking purposes seem to be selected with an extraordinary degree of acumen. They will transplant only such organisms as will not suffer permanent injury by being torn apart. That the growths on their carapaces are placed there by intention and do not affix themselves spontaneously, and that the spider crabs are quite as able to denude as to adorn themselves, becomes readily obvious if we place one in a tank or other environment which contains masking material of a different kind or color than that already covering the animal. If the creature is masked with colors that contrast with its surroundings, it will remove its coat and replace it with one in harmony with the new locality. In making this change, the crab laboriously picks off with one of its claws whatever colors are not in keeping with its situation, the chelipeds being well adapted by their length

and by the flexibility of their joints to perform this operation. Then the animal selects a suitable object and holds the broken portion to the appendages of its mouth where it is manipulated and covered with a secretion of some adhesive substance, after which it is carried with an overhand movement to the back and attached. This is continually repeated until within a few hours the spider crab once more resembles a miniature garden. In addition to the cement they use, some crabs are provided with hooks and barbs on their backs, which aid in holding fast the transplanted organisms.

It may be of further interest to note that among the spider crabs are found the largest crustaceans in the world. These are the giant Macrochiras of Japan, full-grown individuals of which are said to have a leg spread measuring fifteen feet.

The invisibility that the dwellers of the tide pool achieve by color combinations, strange shapes, or masking would seem to be perfect, at least to human eyes—and there is no good reason to believe that the lower animals have a better vision or even one to equal ours. Yet, perfect as is this achievement, it is as nothing, in a way of speaking, compared with that of some creatures in this place, which dispense entirely with such shifts. The glass prawn (*Palæmonetes vulgaris*) is such a one. This crustacean frequently crowds the pool in great numbers, especially in the fall; but so transparent is it that shoals containing hundreds could pass within the observer's reach without his once suspecting it. Only by holding it to the light in a glass of water can its form be seen with any degree of distinctness. Its body is about one and

one-half inches long and it has antennæ that equal it in length. Its legs are remarkably slender and fragile and seem almost too delicate to support even so buoyant a body as the prawn's appears to be; the animal is, nevertheless, a good crawler and gets its food by this means, either on the bottom or on the fronds of seaweeds.

As a matter of fact, all prawns, though capable swimmers and given to migration, are sedentary in their habits, and the majority of species, like many other sedentary animals, are protectively camouflaged. They may be uniformly colored in sundry shades of red, brown, or green, or they may be marked by various patterns of color. These varicolored individuals are usually found among seaweeds which they closely resemble: the blotched and the barred forms, for instance, are frequenters of the larger and coarser weeds, and the lined forms live among the finely branched and feathery growths. There is evidence that these different color patterns may be acquired during the growth of the animal; that is, a young prawn reared among finely branched seaweeds will become lined, while another kept in a tank containing coarse vegetation will in time acquire bars or blotches. Even adult specimens have been observed to change their color after a few days when placed among plants of a different hue, their pattern, however, remaining the same. But here is something still more peculiar: if one of these prawns be put into a white dish, or if kept in the dark, it becomes nearly colorless, and it does so within a very short time. This it accomplishes by a contraction of its pigment cells, or chromatophores, the

substance from these diffusing into the fluids of the body and giving the animal a transparent tint of delicate blue. As this is a phase which under natural conditions is assumed at nighttime, it is interesting to note that chromatophores of prawns kept in the dark continue for several days periodically to expand and contract, the rhythmic movements of the pigments being regulated in a manner corresponding to the alternation of day and night.

The habit of hiding involves none of the freatures of camouflage that we have considered, but it is apparent that the safety from attack which weak animals find in this form of protection is of considerable consequence in their struggle for existence. Very early in my contact with seashore life the significance of this method of concealment was strongly impressed upon me. The incident which I have in mind beside revealing animal behavior, introduced me to that very curious creature, the squid, an animal hitherto known to me only through pictures and writings.

At that time I was quite unfamiliar with many of the tide-pool inhabitants, and the most commonplace of them would hold my wondering attention for hours. A periwinkle making its way over a frond of seaweed, a little horseshoe crab plowing through the mud or a sea worm slowly extending itself out of the slime, were novel and thrilling affairs. A circumstance, too, of no mean magnitude was the molting of a crustacean. Now, a lady crab, in the slow process of shedding its skin, had once engaged my curiosity for a considerable while when eventually I realized by the rising water that the incoming tide had reached the pool and that

further observation would soon be impossible. I was about to wade in to get the animal and place it in a small pool on a higher level when it promptly disappeared with an oblique backward movement into the sand. In spite of the fact that my acquaintance with its ways was limited, this sudden action, coming at the end of a long period of lethargy, and the further fact

LADY CRAB.

that I had as yet made no effort to disturb the creature, struck me at the moment as being somewhat queer. At the same time an equally puzzling performance took place on the part of some small fishes hovering in the vicinity. These—it was later that I learned they were Mummichogs (*Fundulus majalis*)—darted to the bottom and buried themselves, too, out of sight. A suspicion crossed my mind. I had known

birds to take precipitately to cover on the appearance of a hawk in the neighborhood, and this, no doubt, led me to infer that something of a similar nature had caused the crab and fishes to conceal themselves. I was not wrong. On looking around, a sight greeted me that took away my breath. Several yards distant a school of squids was approaching. The animals did not number over a dozen, but the turmoil of sand that followed in their wake and the swift dartings backward and forward of some, made their numbers appear actually greater. The cause of the silty turmoil was soon made clear. The squids were evidently on the hunt for prey. As they proceeded, now and then an individual would descend to the floor and feel over the surface with a pair of long flexible tentacles. Suddenly these organs would encounter some living object lying unseen on the sand, and a short struggle would ensue in which a cloud of silt and sand was raised. A squid would then emerge into view, holding in its monstrous tentacles the unresisting form of a flatfish, and swim away, closely accompanied by a couple of its less fortunate and jealous companions, a hazy reddish trail meanwhile marking its course: the blood of its victim which had been bitten through the back.

Chapter XII

CURIOUS CREATURES

The squid and its allies, the octopus and cuttlefish, have long held an evil reputation. Old books—many of them dating back to the last two centuries—contain pictures and descriptions of huge devilfishes overwhelming and capsizing ships with their tentacles. To these creatures romancers have ever been prone to ascribe a nature and capacity frightful in the extreme. Nor are modern fictionists insensible to the fascination and dread that an artful account of their exploits can inspire. So they often use them in their tales as an aid to excite the imagination. And these colored accounts of the nature and capacity of devilfishes, though less exaggerated than those of older writers, succeed in fostering in the popular mind an impression wholly at variance with what are the actual facts. Indeed, as a consequence, they are generally conceived to be the most fearful of all invertebrate animals.

Marine naturalists give us a quite different version of the activities of these creatures, and from their impassioned reports we learn that the devilfishes are not so black as they are painted; moreover, it is revealed that the leading trait they display in their behavior toward humans is either docility or fear.

Devilfishes, or *cephalopods,* are highly organized mollusks, being very close relatives of clams, snails, slugs, etc., and they are primarily distinguished by their tentacular sucker arms arranged in a radial manner on the head around the region of the mouth. They are carnivorous, or flesh-eating, and subsist chiefly on fishes and crustaceans. There is some evidence that certain squids are at least part vegetarian in their diet, for several six-foot specimens captured off Catalina Island, California, were found to have their stomachs full of seaweed.

Squids range in size from the little *sepiolas* of about an inch long to the giant *Architeuthis,* the largest known invertebrate, which measures, it is said, nearly fifty feet over the entire length of its body. These large creatures are all inhabitants of deep waters, and have never been seen alive near the shore. They are probably very scarce, as few have ever been discovered; even of these, none was in a perfect condition when found, owing to the violence of storms or the attacks of whales. Sperm whales live almost entirely on cephalopods, which they destroy in countless numbers in their excursions through the open sea. The common squids of my vicinity do not attain to more than a foot and a half in length. They are rovers and generally travel in schools, following shoals of young fishes or minnows. Often, however, a lone raider will stalk its prey. And in so doing, it presents some remarkable color changes. This property of changing its color, shared by all cephalopods, is due to the chromatophores covering the surface of its body. The principle on which the pigment cells work is somewhat like that obtaining in the

LOLIGO; A SQUID. (PHOTOGRAPH TAKEN ON THE BOTTOM OF A TIDE POOL.)

iris of the human eye. When the colorless animal is in the act of changing to a darker shade, a dilation of these minute organs exposes a pigmented area; each

chromatophore, like an enlarging freckle, spreads out until it coalesces with its neighbor. These changes—from white to deep mottled brown or full purple, or the reverse—can be produced instantly and can be restricted to different areas of the body, thus enabling it to simulate a pebbly bottom or other environment with more or less fidelity. Few things are more startling to the novice than the rapid flashes of color that pass over these creatures. At one moment it may be of a deep tone contrasting strongly with some shell-covered floor, then suddenly it becomes almost invisible by turning a ghostly white, and will slink away like a specter of its former self. The mode of progression used by the squid is no less curious than its appearance. Its body may roughly be compared to a common force pump wherein water enters at one aperture and is expelled at another. It is the force of the water directed through the "spout," or siphon, located just below the head at the base of the tentacles, that propels the animal. This force is produced by contractions of the mantle, a loose saclike envelope wherein are enclosed the stomach and other vital organs. Usually the squid swims with its so-called tail foremost, but it can reverse its course without changing the direction of its body simply by turning its flexible siphon the opposite way.

In addition to their effective color changes, all cephalopods, with the exception of the single genus *Nautilus,* possess a unique organ, called the ink bag, with which they can render themselves invisible. This organ produces an effect similar to the smoke screen employed by naval vessels in combat. When one of these animals is irritated or pursued, it ejects a black substance

that clouds the water and disconcerts or confuses its enemies.

Although the name "devilfish" is by many indiscriminately applied to the squid, the octopus, and the cuttlefish—and even to many creatures outside of this group—its use in literature seems to be restricted to the octopus; at least this appears to be the devilfish

EGGS OF THE SQUID, ATTACHED TO A CLUMP OF RED SEAWEED. EACH OF THE CYLINDRICAL OBJECTS IS COMPOSED OF A GROUP OF EGGS NUMBERING MANY HUNDREDS.

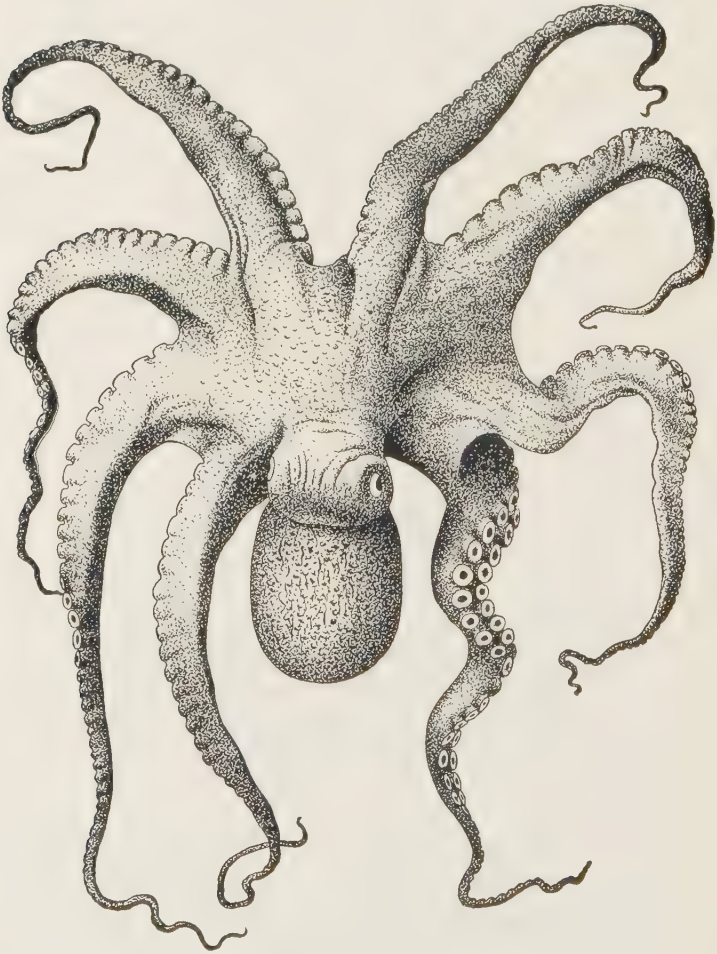
described in the majority of stories; which is strange. For they have neither the aggressiveness nor the huge proportions attained by the squids. It has been extremely infrequent that octopi have been found with tentacles over ten feet long. And even when large individuals are caught they show no disposition to fight

but invariably make a desperate struggle for liberty. Notwithstanding that they have great strength and are armed with a powerful weapon in their sharp parrotlike beaks, they appear to be unaware of their

BABY SQUID; JUST HATCHED. (GREATLY ENLARGED.)

potentially dangerous possession, seeming never to attempt using it in their defense.

An octopus is a timid creature and will usually retreat when a human being comes near it, but it is not a hard subject to study in its natural habitat if one is cautious in one's movements. Like most wild crea-



OCTOPUS, OR DEVILFISH.

tures they recognize as inimical only objects in motion. The difference between a typical octopus and a squid may be stated tersely by saying that the first-named has *eight* long tentacles and a short body and the second-named has *ten* short tentacles and a long body. The relative lengths of the tentacles in both forms will often vary considerably, but their numbers always remain as given. It is because of its comparatively long arms, or tentacles, that the octopus, no doubt, gets its unsavory reputation; these writhing members make it the most hideous and gruesome of all living things. The hard, stony stare of the creature also adds much to the general impression of horror that attaches to one's sight of it; the visual organs of no other animal have the ghoulish, terrifying expression that is in the eyes of the devilfish. This weirdness is even still further accentuated by the insinuating, tortuous movement of the entire body as it crawls from place to place; for, unlike the squid, it seldom swims when it wants to travel. When it does so, however, it employs its siphon and also works its way with rhythmic contractions of a web-like connecting membrane between the bases of the tentacles. For the most part, it remains secreted in rocky crevices, there awaiting its unwary prey, but it has been seen to dash out of the water for several feet and scramble up the dry rocks after a fleeing crab. Seldom is there an escape of the victim, whether it be fish or crustacean, when once the snaky arm, lined with its double row of sucker disks, is shot in its direction; despite its struggles, it is quickly pulled up to the sharp nippers and dispatched.

The female octopus is a devoted parent. She usually

selects for her nest a recess in the rocks below the low-tide level, and guards her eggs with all the jealousy of a mother hen. The eggs, when first laid, are small oval bodies somewhat resembling translucent grains of rice growing around a common stalk. Each one is separately attached to the stalk by a short peduncle, the whole being not unlike a bunch of tiny white grapes. The average number of individual units in the brood of a full-grown female is fifty thousand. She aërates them frequently by manipulating the clusters with her tentacles and directing a current of water upon them with her siphon. Only occasionally does she leave the lair, and then merely for a short time when it becomes necessary to search for food. The brooding period lasts for about seven weeks; at the end of which, the young hatch soon leave to begin a life free from further maternal care. In appearance the new-hatched octopus is greatly unlike the adult; its arms are quite undeveloped and decorate the head like a raked crown.

In the cuttlefish we find a cephalopod having most of the attributes of the squid. That is to say, it is an active swimmer and it has ten arms and a proportionately long, but somewhat flat, body. All but two of its tentacles are relatively short; these two are devoid of suckers along their length except on the club-shaped enlargement at the ends. They are generally kept retracted close to the head and are brought into play only in the capture of prey. It is from the ink bag of this animal that the India ink and sepia of commerce is obtained. This creature is also the source of the familiar cuttle "bone" that is given to caged birds. Strictly speaking, this object is not a bone but is the

internal calcareous shell secreted by the cuttlefish. Cuttlefishes are abundant in tropical waters; I have seen their white shells so thickly strewn on East African beaches that it was all but impossible to keep one's eyes open in the dazzling glare. The animals are harmless and inoffensive to man, and never attain the size of the octopus. Yet, so firmly established is the fear of devil-

CUTTLEFISH.

fishes in general that the most venturesome of a misinformed public will shrink from bathing in waters that are known to be frequented by these cephalopods.

Indeed, the universal prejudice against the larger cephalopods is maintained in more restricted environments. In an actual test made in a marine laboratory where an octopus with arms a foot long was confined, scores of visitors who passed the tank were asked to

touch the animal; yet less than two per cent did so, although in each instance the request was made after earnest assurance was given that the devilfish was harmless and would merely squeeze the hand.

An extraordinary or repellent aspect in a lower animal is an almost certain obstacle to its finding any favor with the multitude. That beauty or ugliness in any creature, as in humans, may often be only skin deep, so to say, seems not to be generally considered. To the true naturalist, however, no creature is ugly. The serious business of his life removes him from those aversions commonly inspired by outward appearances. This happy indifference, of course, most persons do not share. But they ofttimes regard as forbidding, and even unworthy of consideration, many living things which a kindly attempt at acquaintanceship would reveal to be prepossessing and genuinely interesting.

Now, while this is in a deep sense true of that class of cephalopods just considered, it applies with special significance to a group of animals in no way related to them. And this group is the greatest in the animal kingdom. It is the worms. Of all the creatures that are universally held in aversion, none takes precedence over these in popular contempt. Nor is this contempt entirely without cause. The unwholesome experience of mankind, gained largely through contact with degenerate parasitic forms, has done much to create an antipathy toward all the other members of the group. Nevertheless, there is considerable interest attaching to the worms, and a charitable inquiry into their ways will amply repay the investigator. By far the greater in number, both of species and individuals, are those

which live in salt water. Here is to be found every type, from the lowest to the highest, from the most abhorrent to the most attractive, and forms which in richness, variety, or harmony of color are not surpassed even by the exquisite tints of the comb jellies. All show marvelous adaptation to their environment, many exhibit uncommon ingenuity in the construction of their homes, and not a few betray an intelligence that is superior to numberless creatures more highly organized than they. In truth, the simple organization of the worms when contrasted with the complex life histories often prevailing among them, is one of the greatest marvels in natural science. So involved is the development of some of the most abundant forms that years of patient investigation have not yet determined its exact nature.

Perhaps the strangest puzzles occur among the flat worms, the lowest of all worms. There are some which begin life as males, but later in life they lose their masculine characteristics and become females. Others, again, seem to have lost all functions of sex, reproducing their kind by dividing into several pieces, each piece, after growing into a perfect adult, repeating the process.

The largest of the flat worms, and, for that matter, of all worms, are contained in the nemerteans, a class characterized principally by the long, narrow, protrusible proboscis carried by the individuals. A common type is the ribbon worm (*Meckelia ingens*). This animal is found in tide pools secreted under stones or buried in the sand between the tide marks. Its length when full grown is ten feet or more; its breadth is

about an inch. It is flat, extremely soft, and of a pink or flesh color, and in general appearance not greatly unlike the article from which it receives its popular name. Despite its great length, it is capable of contracting to less than a yard; but in doing so, it loses its flat shape and becomes nearly cylindrical. Although it is a most delicate creature, it can burrow with great rapidity when escaping from its pursuer. It does this with the help of its long proboscis, an organ that is also used in determining the location and effecting the capture of its prey. The proboscis, by the way, has no connection with the alimentary tract; it is an independent structure and is extruded through an opening on the top of the body near the forward end. The mouth is on the under side, and is capable of engulfing creatures of considerable size. In accomplishing this, part of the esophagus is thrust out to envelop the object, and it is then withdrawn.

The ribbon worm lives mostly on worms which it finds buried in the sand or mud; although I have frequently encountered it in the nighttime swimming around in the pool, obviously on a predatory hunt. As it extends itself with wavelike undulations over the stony bottom, its proboscis constantly darts here and there among the crevices in search of a victim. Often this will prove to be a member of its own species. Like most nemerteans it is a cannibal, and will readily devour those of its kind which are not too large to be overcome. Its voracity knows no bounds. Nor is the creature exactly discriminating in its quality of food. It will eat worms, such as nereids, which grow numerous spines or bristles. In that event, these indiges-

tible portions often work their way through the intestinal wall and out of the body; but this is in no wise disconcerting to the nemertean, as the punctures heal rapidly, leaving it no worse for the experience.

All nemerteans have the power to regenerate lost parts, which enables them to undergo astonishing injuries without fatal results. They can be cut completely in two, and the fore body will ultimately grow into a

MECKELIA; THE RIBBON WORM, WITH PROBOSCIS PARTLY EXTRUDED.

new and perfect worm, while the hind body will retain its vitality for days before dying. This division of the body can be accomplished by the animal itself, and it seems sometimes to occur as a natural process. Their tendency toward self-mutilation is so great, in fact, that they cannot easily be handled; they will often separate under the slightest touch. The planarians, a lower group of flat worms, possess the power of regeneration in an even greater degree. When they are divided not

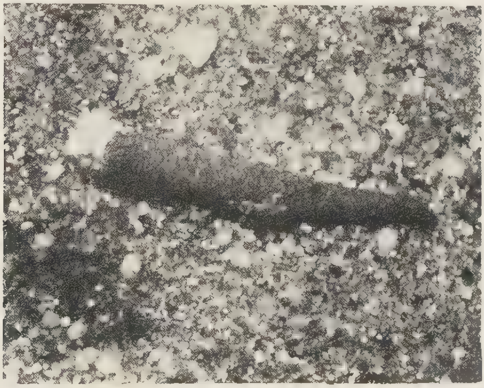
into two but several pieces every piece will live and function as an adult. If, on the other hand, they merely are mutilated instead of cut through, bizarre forms will result from this modified tendency to regenerate.

To exert no more effort in the capture of prey than

EGGS OF A FLATWORM LAID ON THE GLASS SIDE OF AN AQUARIUM. (ENLARGED.)

is required in the normal process of breathing, is the ultimate in solving the food problem. Yet this very thing is accomplished by the serpulids. Scientifically, the serpulids are known as *tubicolous polychæte annelids*. For our purpose, however, it will be sufficient to understand them as tube-dwelling segmented, or ringed, worms bearing bristles—which means precisely the

same thing. These odd creatures are also very beautiful; their variegated colors and conspicuous corollate gills give them the appearance of delicate flowers. A constant circulation of the surrounding water is caused by the cilia on the gill filaments, and these currents produce a vortex that brings oxygen to the gills, and small organisms into its mouth. Serpula, departing from the



THE MASON WORM.

methods of the tube-building mason worm, which constructs its house of agglutinated shell and mineral fragments, and the comb worm, which cements grains of sand together in mosaic fashion to make its free cone-shaped shelter, manufactures its own materials. The structure is a frail tenement, but one of imposing excellence. It is a calcareous tube, winding about over small stones or dead shells, and is, by some mysterious chemistry of the worm's body, converted from the compounds of the sea.

Another instance wherein the gills serve the double purpose of supplying the animal with oxygen and food, but in a manner considerably different, is in the blood worm (*Polycirrus eximius*). It is a segmented worm, deep crimson in color, and adorning its head is a crown of crowded tentacles, or gills, composed of transparent

SERPULA; A TUBE-BUILDING WORM. THIS CREATURE HAS BUILT ITS TUBE ON THE DEAD SHELL OF A WHELK.

filamentous strands that are continuously contracting and expanding. These can be extended to several times the length of the animal's body, the latter being about three inches long. A pair of shorter, branched gills also occur on each segment of the forward half of the worm, while the hinder part is bare. In this creature, as well as many others of its class, the typical crown of appendages that they bear may with equal correctness

be termed either "tentacles" or "gills," as it is evident these are used both for feeding and respiration.

The blood worm makes its home in the mud where it lies buried with nothing but its tentacles showing. These ramify in all directions, suddenly shooting out

POLYCIRRUS; THE BLOOD WORM.

over and under the surface of the substratum, and would be invisible but for the brilliant stream of blood pulsating through them. Its food consists of organisms which are minute but not necessarily microscopic. Sometimes a little Cyclops or a larva of some larger crustacean will brush against the tenuous strands; in-

stantly it is arrested in its course and wafted at once toward the ever-waiting mouth.

Highest of all worms are the segmented forms, and the highest of these are the wandering, or free-swimming bristle bearers. And among them are the most beautiful. The attractiveness of two types, Aphrodite and Nereis, has already been dwelt on in an earlier chapter, so that feature needs no further comment here. Nereis (*N. virens*), however, merits attention for other reasons quite as much as for her beauty. She is easily reared in the indoor aquarium. The activities of few other inmates are more interesting to watch than are hers. When young the worm will make a nest in old shells or under stones; sometimes it will seek a frond of Ulva for this purpose. After growing too large for such quarters—a length of fifteen inches being not uncommon for this animal—she burrows into the sand or mud where she builds another. Her retreat is a tunnel, the lining of which is composed of an adhesive mucus that binds the walls. Quite often it is built in such a manner that she has egress at either end, thus facilitating her escape when pressed by an enemy. Notwithstanding that the diameter of the tunnel is approximately that of her body, she can turn around in it with remarkable ease and rapidity. Here she remains hidden throughout the day, seldom venturing to extend more than half her length beyond the opening. She loves the night. It is then that she becomes quite active. Leaving her burrow she will wander about for hours, and being a fairly fast swimmer, as well as an exceedingly graceful one, the distance she covers is not inconsiderable. In the tanks of my lab-

oratory these worms invariably find their way back to their nests, but it is quite certain that with the larger freedom of their natural habitat, they do not often return to their original homes; therefore it would seem that Nereis is practically put to the necessity of constructing a new shelter at the end of every jaunt.

As to the why and wherefore of this propensity for nocturnal prowling, the reader should have no difficulty in anticipating. It is born of a desire to escape the hunger of others as well as to appease her own. Under the cover of darkness Nereis eludes the vigilance of numerous stronger creatures always on the lookout for such a toothsome tidbit as is she. Some of these, indeed, know where she lives and root her out of her home. At this business, the flatfish is particularly proficient; but probably the greatest enemy of the worm is a creature of another kind, Limulus, the horseshoe crab, an animal which, molelike in habit, leads an underground life for the express purpose of feeding on this and many other worms.

Now Nereis herself is a fierce and voracious huntress. Although she will eat almost any kind of food, plants occasionally included, she is given to the capture of living prey. For this purpose she is well equipped. Her powerful jaws, hard and horny, are very like a pair of serrated sickles. They are set well back in the throat, and in bringing these formidable weapons into play, she everts her pharynx, much as one would turn inside out the finger of a glove; the seized prey is then withdrawn into the throat and torn apart, the jaws doing the work of a gizzard. Nereis, in fact, is possessed of remarkable strength throughout

her body, and is no mean antagonist of many larger creatures. She will easily overpower any other worm, not her species, which is her equal in size. Nor is she above destroying the weaker of her own species when hunger impels. She has a well-developed head on

NEREIS, THE SAND WORM, ATTACKING A SMALLER INDIVIDUAL.

which the eyes, feelers, and other specialized sense organs are located. Her eyes are somewhat primitive in structure and seem incapable of forming a distinct image of surrounding objects; she relies principally on her feelers and olfactory organs to detect the proximity of her prey.

Little is known of the habits of the males, except that during the breeding season, about the first week in July, they swarm the waters in enormous numbers

JAWS OF THE SAND WORM.

after sundown. They are a little more than two inches in length, and the posterior part of their body is bright red and peculiarly modified. They appear to be short-lived, for at the close of the swarming period they are found dead in hundreds, and are not seen again for another year.

Chapter XIII

A "LIVING FOSSIL"

At the northern border of my tide pool, the bottom and the neighboring beach lose somewhat of their sandy character. The region is paved with the stones and pebbles that have been transported here by ancient glaciers. Time and tide have done much to wear them down, and those which are more exposed are flattened in shape owing to cleavage by the frost and other natural agencies. They are of various sizes, ranging from small waferlike pebbles to an occasional bowlder standing as high as my waist. They are of red sandstone and form no part of the native rock that composes the foundation of Lond Island. Whence they came no one knows. Geologists have made several attempts to trace them to their source, but without success.

Now these stones have an interest all their own, apart from the mystery of their origin. If an expert blow be given to the laminated edge of one of the slabs, it will open after the fashion of a ponderous volume, and just as in some long-forgotten tome, wherein is sometimes discovered between the ancient leaves the stark remains of a flower which bloomed in another day, there will likewise be found preserved in the stony matrix pretty plants of a former age. Gone, of course,

is the actual substance of the originals; many, many thousand years have passed since they were resolved into the elements from which they were derived; but the outward shapes remain as perfect as when in that far-distant time they drifted to the floor of some quiet lake or inland sea to become entombed in the hardening silt and sand.

These petrified plants tell an impressive and curious story. They tell us that great and important changes have occurred on the surface of the earth in its past history, changes that occurred not only in the character of the land but in the living things which inhabit it as well. But most striking, perhaps, is the revelation they make in regard to the enormous length of time that the changes involved. The years that have passed since these forms flourished are reckoned only in millions. And yet this duration of time is relatively short when compared with the total time that vegetable life has existed on this planet; for these particular petrifactions are flowering land plants, and in point of time they were preceded by other forms whose beginning was so remote that the significance of the number of years which have since elapsed cannot easily be grasped by the ordinary person.

It is a singular circumstance, however, that so far as actual proof exists in the records of the rocks the origin of animal life was immeasurably distant to that of the plants. The fossils of animals are found in rocks much older than those in which any plant remains appear. But this may be simpler than it seems. The most ancient plants were undoubtedly the soft vegetation of the sea, and, therefore, they were not so easily preserved

AN ANCIENT ANIMAL OF THE SEASHORE. (TRILOBITE FOSSIL.)

as were the hard coverings that prevailed among some of their contemporary creatures.

One of those creatures was the trilobite. And, indeed, its enduring remains are among the oldest of all undoubted and definite organisms found in the primordial rocks. The general form of the trilobite is not

SOW BUGS.

unlike that of the familiar terrestrial isopod crustacean called the "sow bug." After the manner of the sow bug it was able to roll itself up into a ball, and in this position its fossil has often been found. Formerly the two were thought to be related, but, notwithstanding certain of its crustacean characteristics, the trilobite has in recent years been classified with the *Arachnida*, a group including the spiders and scorpions. The truth

is that the systematic place of this ancient creature has always been a debatable one, many naturalists holding quite opposite opinions as to its position among animals. It gets its name from the three prominent lobes, or regions, into which the body is divided: cephalic, thoracic, and abdominal; that is, the regions of the head, fore body, and hind body. Although more than five hundred species are known, many of them diverging widely in structure, they all agree in having a head shield more or less crescentic in shape; and, except in the case of a few blind forms, this head shield bears a pair of large compound eyes. Succeeding the cephalic region is a varying number of free segments, each of which consists of an arched section flanked by a pair of lateral plates. This, the mid-region of the body, is terminated by the abdomen, similarly arched, but having the segments fused.

Fossils of the trilobite in which the appendages of the under side can be distinctly traced, have been exceedingly rare, and only in one genus (*Triarthrus*) is their structure accurately known. In this instance it was discovered that each segment of the body carries a pair of legs jointed to the lateral plates. In the region of the mouth the base of the legs was armed with teeth, subserving the purpose of mastication, or the reducing of its food.

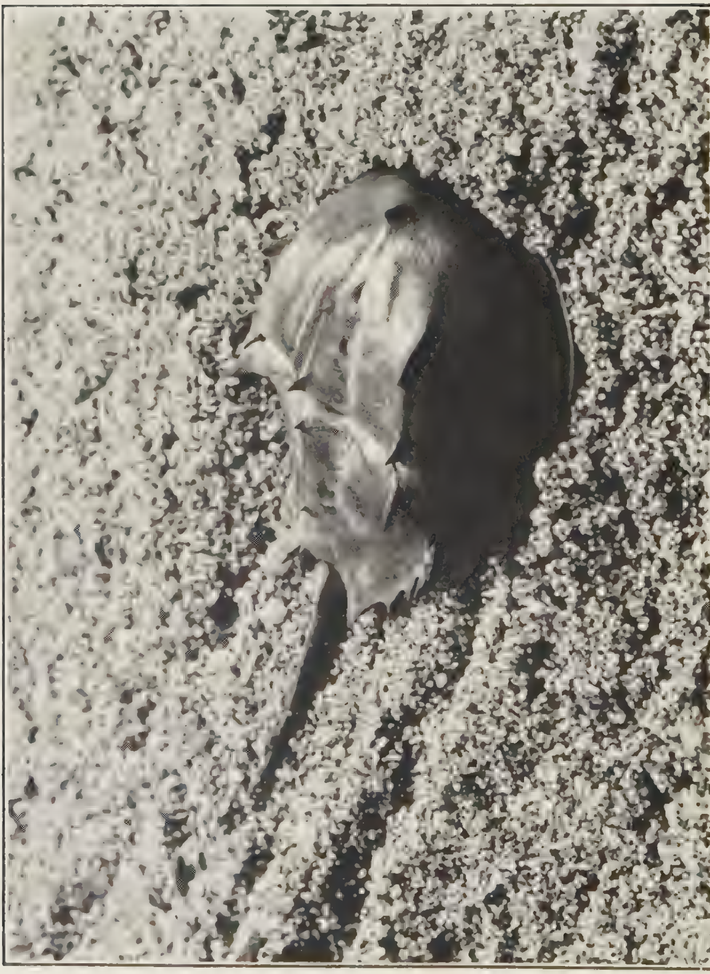
The trilobite, no doubt, lived along the seashore where it slowly plowed its way in the mud and sand after worms and other soft-bodied animals. It probably became extinct long before flowering plants made their appearance on the land; which is to say, it died out about the time the coal beds were formed. The

cause of its disappearance is as obscure as that of its origin.

Although the typical trilobite has ceased to exist, it has living to-day a relative in the horseshoe crab (*Limulus polyphemus*), the sole surviving descendant of an otherwise extinct group of animals. The life history of Limulus is as interesting as it is simple; for in the development of this ancient creature is to be found one of the most beautiful illustrations of that great natural principle which seems to prevail to the effect that the ancestral forms are recapitulated in the embryonic and larval stages of the individual.

The horseshoe crab is found along the whole Atlantic coast from Maine to Yucatan. Although far less numerous than even a generation ago, it is still common enough to be one of the most familiar animals of the seashore. Considering for a moment the increasing scarcity of this creature, it may be stated that in recent years mankind has become more and more aware of its edible properties and of its value as a soil fertilizer. This has resulted in a wholesale and unintelligent slaughter. Naturalists have recorded that as late as the year 1856 more than a million horseshoe crabs could be seen to come ashore and lay their eggs within a single mile along certain sections of the Eastern coast. That this abundance nowhere near exists to-day is ample testimony that their future is very insecure, and unless some measures are taken to preserve them, they will at the present rate of decrease practically be exterminated within the time of men now living.

Limulus lives on sandy and muddy shores below the



LIMULUS; THE HORSESHOE CRAB.

low-water mark. The young, however, are often found in considerable numbers on the less exposed floor of the tide pool, where, molelike, they plow their tortuous way through the upper part in pursuit of worms. The adult animal when full grown is nearly two and a half feet long, and its rounded domelike carapace, or cephalothorax, is about a foot wide. Half of the length is taken up by a slender spinelike tail which is jointed to the double-tipped abdomen. The abdomen is one rigid piece, and is edged with a row of small spines. Viewed from the top, the crescentic outline of the creature compares favorably with that of the object after which it receives its popular name. The head region is strikingly similar to that of the trilobite, even to the large compound eyes that are near each side at the top. It has another pair of eyes, but these are very simple in structure and there is no evidence that they are of any use to the creature. They are located at the base of the first spine on the middle ridge. Indeed, it is very probable that the vision of the horseshoe crab at best is quite crude. Nor is perfect seeing in its case essential. In its underground life of darkness—which is the greater part of its existence—there is little necessity for the use of eyes.

Notwithstanding that Limulus is one of the oldest inhabitants of the sea, it is a very clumsy swimmer. When it does essay to swim, its efforts are usually restricted to gliding in an uncertain manner over the bottom, by a method of locomotion that is best described as half running and half paddling. This observation applies to the adult; when young it manages this thing far better. Whatever capacity the horseshoe

crab has for swimming lies in the leaflike appendages under the abdomen. In this respect its walking legs are very inefficient, but they are eminently adapted to the work they chiefly perform; that is, propelling the animal through the sand and mud. If we examine the under side of this quaint creature, a confusing array of appendages confronts us, but a brief though careful inspection will soon familiarize them. Taking first the head region, we find this forms a great cavity, or bowl, in which are contained six pairs of chelate legs (having claws), and one pair of broad horny plates called the operculum. The first pair of legs is small and lies just in front of the mouth. In the male the second pair of claws is larger than in the female. The sixth pair of legs is composed of large, strong segments like the four pairs immediately preceding it, but its claws are of a diminutive size. These latter legs are further peculiar in that they are modified near the ends into a whorl of three flat or oarlike expansions which spread out in use, thus applying greater surface to the yielding sand. The base of this pair of legs has another process termed the *flabellum*. With the exception of the first pair, all the legs are set at an angle to the body which enables the animal to bring the greatest power or purchase to bear in forcing its way through the substratum. But there is one extraordinary feature of the legs that will strike the most casual observer; for in no other living animal is there a similar adaptation. Nor for the particular purpose it subserves, is there one quite so singular. Like its ancient forebear, the trilobite, the horseshoe crab carries its teeth on its legs. Excepting the first

and sixth pair, the base of each of the others is set with sharp, bristling spines, which, like jaws, macerate or tear the food before it is swallowed.

The operculum acts as a covering for the abdominal appendages, of which there are five pairs and which resemble it in form. These support the gills. The pairs overlap each other to some extent, and each appendage is composed of a broad, thin plate having on its rear surface large leaflike and membranous folds to which are relegated the function of respiration.

Before proceeding with the development of the famous young of Limulus, it may be well for us to observe what part the parents play in their destiny. To this end, therefore, let us see what the beach has in store for us. On my visits there, early in May, when the waters of this latitude have lost their intense wintery chill, I find the horseshoe crab making its first appearance. Throughout the season of cold, it has sought the safety and seclusion afforded by the outer floor of the harbor, where it lies dormant, not, it would seem, buried underneath, but resting somnolently on the bottom. This fact is evidenced by the inordinately heavy growth of hydroids, barnacles, and plants which cover the carapaces of so many returning migrants: a condition that is impossible in an active underground life. The little ones of the tide pool, also, have begun to show themselves. They have, in fact, never left its precincts. With the onset of winter, they dug themselves in on the spot; and now, in common with their elders and many other creatures of the land and sea, they are awakened by the arrival of warmer weather into renewed activity. In the quiet enclosure may be

seen the devious course of many well-marked trails over the mud, at one end of which the vigorous worker reveals itself by throwing up a miniature cloud of silt as it uses its gill plates to sweep the loosened particles to the rear. The telltale trails are of various sizes, ranging from the breadth of my little finger to the width of my hand.

But most interesting is the behavior of the adults. For them I must look elsewhere. On the wide stretch of gravel, sand, and comminuted shells that lies between the pool and the waters of the harbor, are sundry low mounds scattered here and there. They are of the usual size and general appearance that would be caused by throwing up a shovel full of sand. They are not so caused, however; they are produced by mating horseshoe crabs. Each tumulus denotes the presence of a pair who, having been stranded here by the falling tide, pushed their way underneath partly to make a depository for the eggs, but also ostensibly to conceal themselves. Their efforts to conceal themselves, however, are not often successful; they are suggestive of the fabled ostrich, since in many instances it is the female only who hides her head in the sand. She is the larger of the two, and her smaller mate may be seen immediately in the rear with both his heavy claws tightly gripping the two terminal points of her abdomen.

The mating couples do not all take advantage of the tide to reach this strand. Occasionally a female, seemingly unable longer to withstand the urgency of maternal demands, will leave the water when it is low, and proceed up the shore, dragging after her an attendant male with his hold firmly fixed on her abdominal tips.

Sometimes several will follow her. Then occurs a strange procession. Each male hangs on to his fellow in front while she leads the gang to a suitable spot where, after scooping up the sand with her broad head, she at once deposits her eggs. The males then cover them with milt. Whereupon the party breaks up; some of the members return to the water, some await the rising tide. The eggs are some of them later carried about by the action of the waves, but the majority soon settles into the sand, or in the interstices of the gravel to undergo a short—or long, as the case may be—period of incubation.

It may appear from the foregoing incident that my previous statement, concerning the probability of crude vision in these creatures, is somewhat aside from the evidence, that doubtful or imperfect ability to see is not reflected in the facility with which they find their way out of the water to a desirable breeding spot. Well, then, here is my proof. The thing that first struck me that they were practically insensible to surrounding objects through the aid of vision was their utter incapacity to avoid any obstacle happening to be in their way. In traveling over the surface of the bottom, however well lighted, they would collide headlong with stones and other prominent barriers in their path, and only by repeated trial and effort did they chance to circumvent them and proceed in the general direction they were bent. It was the same with the mating individuals who came out of the water to spawn. I would stand directly in the line of their approach, but they would continue straight ahead, heedless of my existence, until brought to a stop by coming into contact with my boots.

Moreover, while in the water, these animals never seemed aware of my presence until I actually touched them; whereupon the merest contactual disturbance was enough often to cause them to strike out for the deeper regions. This is what gave me a hint.

I am going to put the cart in front of the horse, somewhat, by saying at once that Limulus, after the manner of creatures totally blind, makes its way by the sense of feeling, and it determines its direction, or general course, by the slope of the substratum. Let us try an experiment. Taking for the purpose a full-grown individual, we cover both its simple and compound eyes with asphaltum or some other dense pigment—an operation by no means distressing to the animal since in this case the cornea is as hard and feelingless as the carapace. Then placing the creature on the hard-packed sand near the water's edge, we watch its movements. Does it grope about, uncertainly, hesitatingly? Not at all. No matter in which direction it is set—with its head pointed either toward the sea or the land—it crawls unerringly toward the water. In other words, it follows the declivity of the sand, however slight this may be. But in this matter it can be deceived. If it be placed on the side of a ridge that slopes away from water, it will amble to a lower level, and not finding water it will force itself into the sand. By removing the pigment and repeating the process the result is the same. We may be sure that it is by the same principle that the breeding animals are guided in their course up the beach when the water is low. And these journeys are not infrequently over surfaces sometimes comparatively slight in pitch.

For, by covering the eyes of a pair which are obviously about to leave the water, and turning them in the opposite direction, we find that they soon arrive at their destination regardless.

That Limulus can detect light from darkness, there is, of course, no question. This is borne out by the very structure of both the compound and the simple eyes. But this is not seeing, in the sense that humans or the higher animals see. Externally, the compound eyes appear to be divided into a number of circular facets, each barely touching its neighbor. Every facet is the covering of a unit that is a complete eye in itself. In substance, the individual unit is composed of the cornea, which is simply the crust specialized by becoming transparent, and the cone, or crystalline lens. It is this lens that in the eyes of most other animals forms the optical image; but in Limulus it seems to be a very imperfect affair. A continuation of the crust invests the cone which is perforated at the apex, and this in turn is terminated by a rod surrounded with nerve fibrils arising from the optic nerve. The inside of the cone is lined with an opaque pigment that prevents the rays of light from passing from one facet eye to another. The ocelli, or simple eyes, are still simpler in their construction. They are in truth quite primitive. Their pigmentation is irregular and they lack the nervous organization of the compound unit. One peculiarity of compound eyes in general should be mentioned here. It is well known that many insects and crustaceans have remarkable vision. Now, in all those cases in which good vision inheres, the facets of the eyes are arranged in a geometrical pattern as if from compression; viz.,

hexagonal, rectangular. On the other hand, where the facets are mere circular units unmethodically arranged, such as is found in the so-called "silver fish" and certain isopods, quickness of perception is lacking. The eyes of the horseshoe crab are of this type. Just what is the connection between a compound eye composed of a loose aggregation of units and its want of acuteness is hard to determine. Nor is it easy to say why Limulus, which seems to be neither crustacean nor insect, yet possessing two pairs of eyes, one pair actually consisting of nearly two thousand smaller eyes, does not make better use of its endowment. Nevertheless, if one were to hazard the guess that here we see the compound eye of higher animals in evolution, he would probably be not far from the truth. For it is a significant fact that all creatures distinguished by what appears to be this primitive form of compound eye are creatures of a very ancient type; they differ but little to-day from their fossils which were formed millions of years ago. Down through the ages which saw countless other forms appear and then vanish away, they and our Limulus have survived practically unaltered in form.

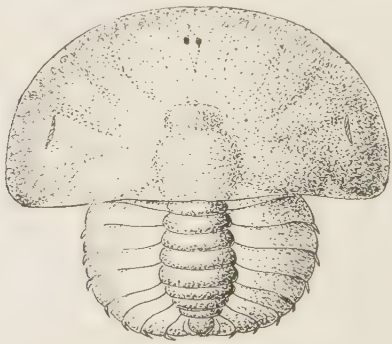
The eggs spawned by a large female horseshoe crab number upward of ten thousand, enough almost to fill a half-pint jar. They are spherical bodies measuring about one twelfth of an inch in diameter. In color they are green. Under the microscope will be seen in each egg a large, smooth granular yolk nearly filling the tough, transparent membrane that acts as a shell. The rate of development of the embryo depends on temperature and, to some extent, light. In a cool place and

dark situation the hatching can be retarded for a year; but under average normal conditions, such as will be assumed to be the case in this account, the period of incubation is far less.

About a week or so after the eggs are laid there appears on the surface of the yolk an oval constriction bearing six pairs of appendages in a row. They are the merest sort of prominences and represent what will be in the adult the legs. At this time, too, a faint indication of what is to be the abdomen can be seen toward one end of the oval. The ovoid region now continues to grow while the yolk gets visibly smaller until the next stage of the embryo is reached, wherein we find not only an enlarged abdomen with four transverse sutures denoting the formation of segments, but a distinct head region on the back of which are strongly indicated five segments. This occurs about three weeks after spawning and by this time the cephalic legs have increased in size, are jointed, and are folded upon themselves, and rudimentary gill feet have appeared on the abdomen. It is now, for the first time, that the embryo shows movement. The membranous shell has increased in size, leaving ample space within which little Limulus continually revolves.

A couple of days later occurs the animal's first molt. Increasing growth has caused it to outlive its old skin, and cast it off within the egg, just as it will continue to do in its larval and later stages. The body is here quite plump, or globular, and is provided with two pairs of eyes, simple and compound. From now on the body gradually flattens. And when, a little later, or about a month and a half after spawning, the egg is due to

hatch, a striking revelation greets us in the appearance of the embryo. It has become distinctly trilobate in character. As in the trilobite, a highly arched ridge runs lengthwise over the middle region of the body, the sutures between the segments of the hind body are somewhat bent, and the outer edge, or lateral plate, of each segment is strongly convex.



TRILOBITELIKE LARVA OF THE HORSESHOE CRAB.

Finally the membrane ruptures and liberates the larva. The larva differs from the embryo in that the abdomen is broader and flatter, and that the sutures between the lateral plates have disappeared, leaving segmented only a keellike middle ridge. It is now a little more than a tenth of an inch in length and a trifle less in breadth. Immediately it shows great activity by vigorously striking out into the water and swimming away. For about three weeks it lives a more or less nomadic life, wandering widely in this period, when at the end it molts and settles to the floor for good. With

this molt it loses entirely its segmented appearance and now more nearly resembles the adult. A short spine-like tail adorns the abdomen; the abdomen is thin, and this region, like the cephalothorax, is hollowed out underneath, the whole forming an ample shield for the legs and gill feet.

HORSESHOE CRAB MOLTING.

When Limulus is a year old it attains to an inch in length; by then it has molted several times. But not before it is in its fourth year does it reach sexual maturity. In that event the male acquires the strong front claws that distinguish his sex.

Thus, in following the development of Limulus, we see revealed with remarkable distinctness its ancient origin. It is not always so easy, however, to trace the

antecedents of our higher animals. The threads that unite them with the past are often tangled and sometimes broken. But all such as we have been able to guide ourselves by lead to the inevitable conclusion that, like the horseshoe crab, every other living many-celled creature had its beginning in a form which has now long since perished forever. And it is to the story of the unraveling of those strands and the uniting of the broken ends that natural science owes some of its most thrilling, most romantic, and most luminous pages.

Chapter XIV

MORE FRIENDS IN ARMOR

How "fiddler crab" came to be the popular name of the crustaceans which forms the subject of this chapter is not easy to determine. On consulting the books, I find reasons as various as they are numerous. The most likely explanation, perhaps, lies in the allusion to the single enormous claw carried by the male. It is said that the back-and-forth movement of that claw resembles the act of fiddling. Well, this may appear so to some people; but it seems to me a far-fetched peg upon which to hang a name. The Japanese have a more apt and much prettier term. They call it *siho maneki*, "beckoning for the return of the tide."

Whether right or wrong, its common name is at least definite and durable. It has never been known by any other English name; and when one speaks of a fiddler crab there is no misunderstanding as to what sort of creature is meant. The nomenclature of science has not been so happy. Since the fiddler crab has come under the cognizance of the learned systematists, it has paraded under at least four different formidable Latin terms, and all of them of an even more doubtful significance than that which is born by its popular one. An instance in point is *Gelasimus pugilator*. This name,

meaning "a laughable fighter," is given to a crab of my region. But in my contact with it in the salt marshes, where it honeycombs the ground with its burrows, and where it is to be observed not in hundreds, not in thousands, but in millions, I have not yet seen the least display of pugnacity toward its fellows or toward humans. *Uca minax,* "the threatener," the present name of the species whose habits I propose to describe, is hardly less inept. It is true that none among our armor-bearing creatures wears so threatening a panoply, but the male, in his possession of a clumsy and apparently quite useless claw, is far from a threatening creature. This prodigious appendage is entirely wanting in the female, whose chelipeds are small and of equal size. Just why the male, who generally carries it at rest across the broad front of his carapace, is thus distinguished does not seem clear; for at no time does it appear to be anything but an encumbrance.

Our fiddler crab (*Uca minax*) is not a large crab, as crabs go, being not much more than an inch and a quarter over the breadth of its carapace. It likes to live in a region of brackish water, on the open, sandy reaches at the very upper limits of the tide near where the marsh grass starts to grow. Here it depends for food on the minute algal deposits left twice daily at its door by the tides. Vegetable matter is not its whole diet, however; it will greedily attack any bits of carrion which chance to come within its range. It prefers its victuals fresh. Unlike the true scavengers of the shore, its meat must have no suspicion of being stale. But opportunities of this kind are rare, and it is perforce obliged to subsist for the most part on what plants will

suit its taste. Whenever it leaves its burrow—and it seldom wanders from it more than a few feet—it can be seen picking about in the sand and silt, carrying the all but invisible motes of matter to its mouth. Some of this matter is sand; mixed with it are the food particles that it seeks. For this burrowing animal, in learning

FIDDLER CRABS. THE MALE, WHO IS READILY DISTINGUISHED BY HIS LARGE CLAW, IS TOWARD THE LEFT OF THE PICTURE SITTING IN THE OVENLIKE ENTRANCE TO HIS BURROW. THE OTHER INDIVIDUAL IS THE FEMALE. PELLETS OF EXCAVATED SAND CAN BE SEEN IN THE FOREGROUND.

to live on land has learned the same lessons as the earthworm: in the absence of more available products, it eats the soil to live.

The burrow of our fiddler crab can readily be distinguished from those of other species by the archway, or ovenlike mound, over the mouth. Many of these ovens will be found within the space of a single yard.

After the frosts have gone they begin to make their appearance, and by the time the scorching heat of summer has set in they become so numerous along the edge of the marsh that they are countless. The diameter of the shaft varies; those of the young are less than the thickness of a match, while the adults sometimes make holes into which a hen's egg could be dropped. These latter are sunk to the greatest depth; they rarely reach more than a foot. At the bottom a horizontal tunnel less than a finger's length is often, though not invariably, projected.

Excepting during the breeding season, only one crab occupies a burrow. When the tide is out, this individual can be seen sitting for long periods in the arched doorway, without movement or any sign of life other than an occasional twitch of its eyestalks. But it is fully alive to what is going on around it; if the observer so much as raises an arm, the creature disappears instantly down the shaft. Then, if one waits for a while, one will see it cautiously and slowly reappear to take its place at the entrance.

Since the fiddler crab makes its burrow at or very close to the high-water mark, its home is inundated for only a short while at each flood. This allows it ample opportunity to wander around. Yet it never goes far afield, seeming to prefer its doorstep to the allurements of travel. It is certainly not due to any inability to get over the ground that it chooses to lead a sedentary life. It is, in fact, a very nimble runner. When surprised at its business of searching for food some few feet away from its hole, it will rush to its retreat with remarkable speed. And to intercept it, one must be more than

ordinarily agile, for so alert is the animal that, on finding its way blocked, it will scamper down the nearest of the neighboring burrows. Still, in spite of its activity and the protection afforded by its place of hiding, it is the prey of numerous enemies. These are chiefly birds. The blue heron knows its habits well. This long-billed and long-legged creature stands motionless over the burrow waiting for the crab to come out, and no sooner does the latter make its appearance than it is silently and swiftly snatched from the ground and devoured.

Although the fiddler crab seems not yet to have learned how to escape its enemies of the land, it has an inheritance that stands it in good stead in avoiding its foes of the sea. But dangers from that direction are few. It is extremely infrequent that the crab finds itself unexposed on the bottom. When it takes to the water at all it is in some shallow pool or equally safe and sheltered place right at its door. When the tide rises over its burrow it rarely ventures out, but remains secluded within until after the flood subsides. The peculiar marbled pattern on its back, together with the translucent appearance of the legs, make it barely distinguishable in the water from the sand on which it rests. It has some facility in changing its hues from lighter to darker tones, according to its situation, and almost every color of the rainbow is represented on some part of its body: from the bright red of the joints on the legs to the soft blues and greens and buffs that beautify its back, the range of tints is so wide and their nuances are so exquisitely delicate as to make it easily among all brachyurans the most charming to the eye.

This is to say, while it is in the water. Out of that medium these features lose their delightful characteristics. And, furthermore, it is on the dry land that the creature spends the greater part of its existence; so, in a sense, the beauty that is the fiddler crab's is attained under unusual, if not unnatural, conditions.

Now it must by no means be assumed that the crab is a terrestrial animal living in proximity to the sea, that it could live, if need be, on the dry land. The truth is quite the reverse. It can be kept continuously in the water without harm. Nor will it long survive its absence. In a way of speaking, water is to this creature the very breath of life; but it gets all that is necessary for its needs during the short time it is submerged by the tides. Except for this temporary, but very vital, contact, it has slight acquaintance with an aquatic life.

How does the fiddler crab breathe? How is it that a creature possessing only gills, which we know are strictly water-breathing organs, can with equal facility breathe in the free air? Strictly speaking, it does not breathe the air direct. Its gills lie in two large cavities on the back just under the carapace. These cavities, or chambers, are considerably larger than the gills themselves and are in reality receptacles for the storage, or retention, of water. When the crab is submerged, an opening to the front of the chamber allows a free circulation of water to enter and bathe the gills, which absorb the necessary oxygen to sustain the animal. Out of the water, however, the opening closes, and the retained water absorbs oxygen from the atmosphere, which in turn is transmitted to the gills.

When the rising tide reaches the level of the

burrows, it finds every crab safely underground, completely out of sight. More: it finds the ovens demolished and the entrance to the shafts plugged up with sand. In truth, our fellow knows well the time of high water, it seems, for it anticipates its arrival by having sealed its shaft within a half hour of the moment it is submerged. For the purpose of stopping up the hole, the crab uses the material of the archway and scrapes up what is necessary from around the door. This it gathers up in great pellets and packs solidly at the mouth, forming a plug an inch or more deep. The advantage in thus stopping up the shaft is obvious. It saves the inmate an enormous amount of labor. Were this not done and the holes left open, the action of the water would fill them with silt or cause the sides to crumble in, and by thus burying the occupant cause it no small inconvenience and hardship by obliging it to construct its entire burrow anew after every inundation.

Even as it is, the crab is put to considerable effort when the tide lowers. For the seepage of the water loosens the wall which in the first place is none too well consolidated, and some sand invariably falls away from the sides. To reopen the passage, it first pushes up the sand that plugs the entrance. This loosened material forms a mound at the top, and the crab works its way out at the base, which results in giving to the little tumulus its ovenlike character. After which the animal returns to the burrow and scoops up a load of sand, compacting it into a pellet of about the size of a cherry, and proceeds to carry it out and deposit it a few inches from the mouth. This performance is repeated several times until the tunnel is thoroughly cleared, the crab in

its sidewise progress pulling the pellet along by holding it in the hollow formed by the curvature of its rearward legs. Every burrow has a number of these characteristic pellets in its vicinity. At best, the burrow of the fiddler crab is a temporary affair; the animal alternately building and abandoning many homes during the course of the summer.

I have alluded to the presence of more than one individual in a shaft. With the arrival of summer comes the call of love. The amorous pairs, whose embraces last the greater part of a day, seek the seclusion of the horizontal tunnel at the bottom for their tryst. Throughout the whole of June, I find, on prying into various retreats, many couples so engaged. At this time, too, the male seems heightened in color, the red patches on his ponderous cheliped becoming decidedly garish. He affects his best raiment for the wedding. The marital life is not for long, however; no sooner have they relinquished their embraces than they separate for good.

During this month many females can be seen bearing a large, dark-red spongy mass on the abdomen. It would not be hard to guess, even without the lens, that this sponge is a batch of eggs. But the jars of my laboratory will give us more information about them than could possibly be obtained at the beach. So let us collect a few of these fertile females: the thing is easy, a thrust of a spade will quickly unearth any who have disappeared in their burrows. Then transferring our pretty creatures to a pail of salt water, we take them home. One point should be noted here which may be of value later in our observations: contrary to the usual

habits of the fiddler crab, some of the sponge-bearing females spend quite as much of their time in the water of the neighboring pools as under the archway of their ovens.

With our captives installed in two-quart jars, half filled with sea water and a layer of clean sand on the bottom, we await developments. Each tank holds one

FEMALE FIDDLER CRAB. THE DARK MASS ON HER ABDOMEN IS A BROOD OF EGGS AND IS KNOWN AS THE "SPONGE."

female, and her jar is kept nice and fresh by the addition of a frond of sea lettuce. A cool, well-lighted place at a north window insures results more nearly approaching those under natural conditions. In the meantime a closer inspection of the animals may be profitable.

It was pointed out in an earlier chapter that the true crabs, or brachyurans, in contradistinction to the lob-

sterlike crustaceans, or macrurans, have a relatively small hind body. In the fiddler crab, which is a typical example of the Brachyura, the cephalothorax, or the fore body, is flattened and broader than it is long. The small, flat, segmented abdomen is folded under the fore body and fits in a depression, making it appear to ordinary eyes as if the creature's entire body were one rigid piece without a division of hind or fore body. As a matter of fact, the abdomen, though invisible from above and inconspicuous when the animal is viewed from underneath, is a very important part of the crab's anatomy. In the male it carries the external parts of the sexual organs, while in the female it has on the under, or what may appropriately be termed the inner, side four pairs of prominent hairlike appendages called the swimmerets. It is to the swimmerets that the extruded eggs are attached, forming the spongy mass. It may be added that the hind body of the male is comparatively narrow, whereas that of the female is very broad; a feature that readily enables the determination of an individual's sex, which is not always obvious in the case of the males, who ofttimes have lost their distinguishing claw.

The eggs in reality are divided into eight clumps corresponding to the four pairs of swimmerets, but they are so closely packed that they seem to form one large group. The mass is flattish and seems to be wedged solidly between the thoracic region and the abdomen; its bulk is about that of a navy bean's. But so small are the individual units that more than seventy-five thousand are contained within this space. Herein is the secret of the fiddler crab's persistence, who, de-

spite its manifold enemies, succeeds in maintaining its enormous numbers. The microscope, that third eye of the investigator, tells us that each egg is attached to the fine hairs on the inner branches of the swimmerets by a stalk. The stalk is a continuation of a membrane investing the egg and the hair to which it is fastened. Numerous eggs are fixed to the same hair, and the whole is not unlike a long stem supporting a cluster of berries by short pedicels. The eggs are fertilized while in the body of the female. When first laid they are of a deep orange color, but soon turn dark red; and as hatching time approaches, they become a deep brown, due to the black eyes of the growing embryo.

Within a fortnight after the jars of my laboratory are established, my anticipations are realized. Every one of the females has hatched her brood. My attention is first attracted to this event by a cloudlike haze on that side of the tanks which is nearest to the light. This observation may give us some idea of the length of time the mother has been burdened with the eggs.

A dipping tube inserted into the hazy swarm takes up hundreds of the young larvæ, and a drop of water released on a microscope slide brings several within easy compass for observation. Under a low-power lens the little creatures can be seen actively cavorting across the field, their movements closely resembling the wriggling progress of mosquito larvæ. They are translucent throughout their bodies, except for the large, prominent compound eyes, which are black. There is no similarity to their parents. The head and front part of the body are covered with a helmet-shaped carapace

having a long curved spine standing out from the middle of the back, and another straighter one projecting, like a beak, in front. The hind body is much smaller. It is narrow, segmented, and ends in a forked tail, or telson. It is also very flexible, and can be bent under the fore body or straightened out behind. There are several pairs of delicate appendages on the fore body, but the most conspicuous are the two pairs of swimming legs ending in featherlike branches. Actually, the two-branched swimming legs are appendages belonging properly to the mouth, the real legs of the crab being not yet in evidence, and, although the segments of the abdomen are distinct, they are devoid of swimmerets.

This description of the first larval stage of the fiddler crab applies with almost equal correctness to the newly hatched larvæ of every member of the marine Brachyura, or crabs. It is a typical form and for that reason it is known as a *zoëa,* a name which it received when it was thought to be a separate and distinct species of crustacean. Some land crabs differ slightly in their earliest larval appearance. That the zoëa were once thought to be an independent species was due to the fact that the development of the fresh-water crayfish was known long before that of other crustaceans. In that creature the young when hatched from the egg are practically like the adult, and it was therefore assumed that all crustaceans were developed alike. Indeed, the larval stages of marine forms were known, but their actual identity was not suspected. And even after their true nature was discovered, after their metamorphoses had been studied and described, many

eminent naturalists "refused to believe in the possibility of their occurrence."

The next and last larval stage, which is also peculiar to the crabs, takes place in our animal about a month later. In this stage the larva, known as a *megalopa,* spends most of its time swimming about at the surface

ZOËA OF THE FIDDLER CRAB. (GREATLY ENLARGED.)

of the water. From the evidence of its behavior in the tanks, it is plain that during this period of its life it roams far and wide. Then it is that the necessary dispersal takes place to prevent overcrowding in one locality. It has shed its zoëal skin, and now appears with all its appendages. The spine on its back is missing, the one in front much shortened, and its eyes are stalked and movable; except that the hind body is

extended straight out in the rear instead of being bent under the fore body, it does not differ greatly from a little crab. It is by means of the swimmerets on its abdomen that it propels itself, and in view of the natatory life led by the larva it is easy to understand the predilection of the burdened female for the water. Were her tender babes to burst their swaddling clothes while she sat on the scorching sands, their lives would be in grave peril. But just as frequently, she remains in the humid retreat of her burrow when the hatching is due to occur; the little ones later finding their way out in the waters of the tide.

A week or so later the megalopa molts; this molt bringing it directly into existence as a young crab. The little creature, who is not much larger than the head of a pin, immediately settles down in some likely area near the high-water mark and starts to burrow.

From now on it will live like its elders, picking what it can find to eat from the sand and silt. Without going into tedious details, I can say that from what deductions are possible from my tanks, and from further observations at the shore, the probable developments in the future life of the fiddler crab are as follows: Full growth is not attained until it is nearly a year and a half old; that is, in the fall of the following year. This growth is signalized by successive molts which occur at least twelve times. The castings of the crust take place more frequently in the early than in the late part of the animal's growing life. After it reaches maturity, the moltings no longer occur. There is evidence that pairing happens during, or shortly subsequent to, the molting period of the female. Other

evidence suggests that the female may have more than one brood after a single meeting with the male, and that she dies soon after her last bearing. The crab's term of life is three years.

To say that the fiddler crab grows when it molts would be to express the reverse of what is true. The fact is, the creature molts because it grows. The soft tissues increase in content, but the hard, rigid armor is incapable of expansion; therefore this must be cast off. In the process of shedding, a crack appears in the crust along a line at the rear edge of the carapace. The crab literally backs out through the opening thus started, and as it does so it forces the carapace up, extending the fissure on both sides to the front, making its egress easier. This operation is performed by a series of peculiar rhythmic tremors, and it takes about twenty minutes to accomplish. When the animal is finally divested of its shell, it appears soft and wrinkled on the surface, and, although it can walk, it is truly a quite helpless individual. Were it not for the fact that this critical period is passed in the saturated precincts of its cell, it would, besides running the chance of succumbing to the first evil passer-by, be subjected to considerable discomfort in the rays of the sizzling sun. But it soon fills out and the skin begins to harden. A day or so hence finds it once more sitting in the doorway or picking at the sand.

Molting has its advantages in other ways. If a young crab has lost an appendage a new one appears at the time of some successive casting of its armor. It is a common phenomenon among crustaceans to throw off a leg or claw when the individual is seized by one

of those members. This is an automatic process, which is to say, it is not due to external force as such. Technically it is known as autotomy, meaning "self-cutting." The separation of the appendage usually occurs at a point on one of the segments close to the body, and serious as it may seem at first sight there is little danger to the animal; the tissues of the stump constrict, thus preventing excessive bleeding, and the loss is often only temporary. If it happens just after the crab has shed its skin, another takes its place at the following molt; if the loss is sustained a short time before the shedding, the second succeeding molt will complete the regeneration.

From this it would appear that the full-grown animal, having completed all the molts necessary to attain its growth, is unable to regenerate lost appendages. So far as my observation extends, this is actually the case. Yet an old crab will as readily cast off a claw as will a young one. It is plain, nevertheless, that in any event this capacity is to its decided benefit; for, truth to say, it is better to lose a limb than to lose a life.

PART THREE

THE OPEN SEA

CHAPTER XV

BEYOND THE HORIZON

IT is a remarkable fact that there are few living marine animals which are more constantly brought to notice than those ranging the open sea, and yet there are not many whose habits and life histories are more completely unknown. The very nature of their haunts, of course, makes it more difficult to observe them than would be the case if they were associated with the shore. What information has been obtained regarding their food habits has been derived not so much by actual observation as by the more indirect, but certain, method of examining the stomach contents of captured specimens. However, except in relation to a few forms, positive information of the behavior and development of the vast majority that roam the deep is extremely scant.

Examination of the ingested food of oceanic animals, by the way, has revealed the existence of many creatures hitherto unknown. Whales and large fishes are particularly valuable in this respect; in their predatory excursions they pick up more strange species than do the nets of the naturalists.

Probably none of the sea rovers are as often connected in the popular mind with the open sea as are the

whales and sharks. Much misconception, however, exists regarding these creatures. Each comprises a numerous group. Not all whales are the large, picturesque animals romantically featured in stories; not all sharks are dangerous.

The whales, in modern classification, belong to that order of mammals distinguished by the Greek name *Cetacea,* a word meaning "sea monster" and once indiscriminately applied by the ancient mariner of the Mediterranean to all large and strange oceanic creatures. Now, as the cetaceans are mammals, and since we know that mammals are warm-blooded, lung-breathing animals which suckle their young, it will be seen that the whales are very far from being fishes. In the whales, however, the hairy coat that is usually characteristic of mammals has almost entirely disappeared, its property of protecting the animal from the cold having in this instance been assumed by the thick layer of peculiar fat, called blubber, under the smooth skin. The only reminder of a former hairy coat is to be found in some very young whales, wherein the presence of a few bristles about the lips indicate a hirsute ancestor. Indeed, one of the striking characteristics of these creatures is the total dissimilarity of their outward appearance to other mammals. Even internally many modifications are to be found. The hind legs have disappeared, but they have left within the body remnants of the pelvis and thigh bones; in some instances the leg bones themselves still remain. The peculiarity of the fore limbs is quite marked in that the arm bone is very short and broad; whereas in other mammals all agree in having the same number of joints

in the fingers and toes, in the whales these numbers invariably are exceeded. In some instances the fingers have more than twenty joints, a feature greatly resembling the many-jointed flipper of the extinct Ichthyosaurus and allied prehistoric marine lizards. The flippers, usually small though sometimes of considerable length, are not used to propel the animal in swimming, seeming to be more for the purpose of maintaining its equilibrium or keeping it on an even keel. It swims by the sculling action of the flukes of its great tail which is not placed vertically as in fishes, but horizontally. This position is better adapted to the requirements of the animal which must needs often seek the surface for air to breathe.

Cetaceans, although having many features in common by which they are easily identified from other mammals, nevertheless differ considerably from one another. As I have already observed, one of these differences is in respect to size. Some, the smaller dolphins, are less than a yard long; the other extreme is found in the blue whale, or rorqual, which is said to be nearly ninety feet in length. But there is a more fundamental difference than that of mere size; and it is one which has caused them to be divided into the two great groups that naturalists now refer them. These are the whalebone whales, or the *Mystacoceti,* and the toothed whales, or *Odontoceti.*

Even the members of each of these groups exhibit enough differences to make further divisions possible. The whalebone whales are split into two families which in turn are subdivided into genera and species. In one family are included the so-called "right whales," and

in the other are the rorquals and the humpbacked whales. But the difference between the families is one of degree rather than of kind. In the right whales, known technically as the *Balænidæ,* the whalebone is very long; in the other whalebone whales, the *Balænopteridæ,* the whalebone is comparatively short. Furthermore, the right whales have no dorsal fin, while the rorquals invariably are possessed of this appendage, though in some specimens it is rather small. Another means of identification for those who chance to meet

GREENLAND WHALE.

with them at sea is by their manner of disappearing under the surface. The right whales dive with the great head almost straight down into the water, throwing upward the flukes of the tail, while the rorquals, on the other hand, sink out of sight gradually, much in the way that a submarine boat disappears from view.

The most famous of the right whales is the Greenland, or Arctic, whale. This is the true polar species, seldom or never being found far from the Arctic ice. It was at one time the object of a great European fishery. Holland, England, and France were chiefly engaged, but a large Dutch settlement in Spitzbergen employed no less than 260 ships and 14,000 men in

the profitable business of hunting and killing these creatures. That was in the seventeenth century when the whale fishery was at its height; to-day the Greenland whale is practically extinct. It has entirely disappeared from the region of Spitzbergen and the waters of Greenland where it once existed in such plenty, and now only a few small wandering herds may occasionally be encountered in the neighborhood of Bering Sea.

This species (*Balæna mysicetus*) is the largest of the right whales, reaching a length of about fifty feet. Over the back and sides it is a deep blue black, underneath it is gray, while the neck and throat are white. The enormous head fully exceeds a third of the creature's total length. Actually, the cavity of the mouth is larger than that of the body. Yet as gigantic as are the jaws of this animal, the gullet is comparatively diminutive, being less than two inches in diameter, and it subsists on nothing but very small organisms. Its food consists principally of minute crustaceans and free-swimming mollusks (*pteropods*), which swarm in immense shoals in the colder seas. In the capture of its food, the value of its inordinately large mouth becomes at once apparent. It is thereby enabled to engulf at one time a sufficient quantity of water containing the organisms. When the creature closes its jaws, these are held in by the straining action of the whalebone which allows only the water to pass through and out at the sides of the mouth. The whalebone blades in the animal are not exactly as they appear in the article with which we are all more or less familiar; they are here frayed out at one—the inner—edge and at the ends into long soft and silky but extremely tough hairs.

They hang in two rows from the upper jaw, a row on each side of the mouth connected by a group of shorter blades in front where the jaw arches down, but those in the middle where the arch is highest are very long. Sometimes they have a length of twelve feet. There are nearly four hundred on each side, and the whole quantity in the mouth of a large specimen often weighs close to two tons.

Many species of right whales have been described, but naturalists are not quite agreed as to their number or distinctive characteristics. For instance the Biscayan whale (*B. biscayensis*) is supposed by some to be identical with the black whale (*B. australis*). The former differs from the Greenland whale in having a smaller head and a correspondingly shorter length of whalebone. This species frequents the colder waters of the northern hemisphere, but its range is very wide, having been found as far south as the Azores and Bermuda and even in the Mediterranean Sea. It was once thought to be extinct; it has, however, been seen recently in considerable numbers in the North Atlantic. The black whale inhabits the southern hemisphere in the neighborhood of Australia, New Zealand, and the Cape of Good Hope, in the latter region of which I have been so fortunate as to sail through several small herds of them. That was more than twenty years ago, and it would be nearly correct, perhaps, to say that the black whale no longer inhabits the southern seas, for owing to the wanton slaughter of the females as they visited the coastal bays and inlets to breed, their extermination is almost complete. Another right whale is one (*B. japonica*) which ranges the northern half of

the Pacific Ocean from the Siberian Sea of Okhotsk to Oregon. The Japanese from very early times have hunted these creatures; however, in late years the American and Russian whalers have made considerable inroads on their numbers. Here, too, the specific difference from the Biscayan whale and the black whale does not seem to be well marked. The condition in which they are brought to shore does not make it easy for thorough comparisons. It is probable, though, that if any differences do exist, they are very slight.

RORQUAL.

The rorquals and humpbacked whales resemble the right whales in their habits, and except for the presence of a dorsal fin and having much smaller heads, they correspond with the other in general structure. But a peculiarity exists in the appearance of these animals which is unique: the skin under the throat is lined in a lengthwise direction with long parallel ridges and grooves, or plications. As I have said, some of the rorquals have been alleged to measure nearly one hundred feet; they are larger than the right whales, and indeed are the largest of all known animals, living or extinct. Of all the whalebone whales they are the most abundant and widely distributed, being found in almost every sea. They live on minute organisms,

but some will feed on fishes, for they have often been observed feasting among herring shoals and schools of an Arctic species (*Osmerus arcticus*).

When we turn to the toothed whales, we find not merely a difference in the dental equipment but there is a marked change in the food habits and generally in geographical distribution as well. This group, the *Odontoceti*, is a numerous one, the most noteworthy of which are the sperm whales, dolphins, and porpoises. The largest of these is the sperm whale (*Physeter macrocephalus*), known sometimes as the cachalot,

SPERM WHALE.

which attains to a length of over sixty feet. Its characteristic gigantic head, with the straight, blunt forehead, is an enlargement caused by the presence of a huge mass of waxy substance (*spermaceti*) in this region. The mouth is on the under side of the head, and is somewhat behind the end of the snout. The teeth are large and conical, and confined to the long, narrow lower jaw. They number about twenty-five on each side, and are of a very good quality of ivory. In common with several of the other toothed whales it lives mostly on squids and cuttlefishes; nevertheless, fishes of considerable size are often a preponderant part of its diet. It is likely that the cephalopods it

eats give rise to the peculiar product called "ambergris," the concretion of its intestine which usually contains the beaks of those creatures. This substance was formerly used in medicines but is now a constituent of the finer perfumes. It has no fragrance of its own, but it has the property of enhancing the scents with which it is combined. It is generally found floating on the surface of the sea or cast up on the shore, and, as it is one of the costliest articles of commerce, it can bring its chance discoverer a handsome reward. The sperm whale is a native of tropical and subtropical seas; but, in their breeding places in southern latitudes, the old bulls in their fights for possession of the cows drive from their haunts the young males; and these, in wandering over the ocean after defeat, may in a sense be said to have a cosmopolitan range.

As might be inferred, the possession of a set of powerful teeth is not attended without a certain degree of ferocity. Such, at any rate, is the case with the great killer whale, or grampus (*Orca gladiator*), the fiercest of the family. This beast is a dolphin and is the largest of those animals. It measures some thirty feet long. The conspicuous light-colored bands with which its body is marked serve to emphasize its somewhat forbidding appearance. Seals and porpoises are not uncommon among its captures; and it will boldly attack whales even larger than itself. One naturalist has recorded that he took thirteen porpoises and fourteen seals from the stomach of a single individual. The grampus roams the northern seas. It sometimes hunts in packs; and whales of goodly size have been known

to throw themselves ashore in their efforts to escape these marauding bands.

To the dolphins, also, belongs that odd creature the sea unicorn, or narwhal (*Monodon monoceros*). In this whale the teeth are undeveloped, save in the male who has one long twisted tusk that projects straight out in front fully one half the length of the body. As the narwhal is twelve feet long from snout to tail, it will be seen that this tusk, notwithstanding that it has a narrow central cavity, constitutes a considerable piece of ivory. It is, in truth, hunted only for this tusk, the whalers seeming to attach little value to the carcass. Despite the formidable aspect of the tusk, its use to the animal is very obscure. Certainly the narwhal does not —as does the swordfish—charge boats and pierce them with its weapon. Nor has it been observed ever to use it in any other manner, offensive or defensive. It is a peaceable and even a playful creature; and this, together with the fact that it swims in small herds in the icy waters of the North, where it feeds on small fishes, crustaceans, and cuttlefishes, is about all that is known with certainty regarding its habits.

Closely akin to the dolphins are the porpoises. The fact is, between the two the fundamental difference seems slight, and what does exist is to be found chiefly in the dentition of these animals. The teeth of the typical dolphin are conical and pointed, and in numerous ways they strikingly resemble those of reptiles; whereas in the porpoise the teeth are grooved and flattened, or shovel-shaped, at the crowns. Porpoises are without doubt the commonest of all the cetaceans. But the majority of species frequent the coasts, bays, and

sometimes even rivers, rather than the open ocean. Their average length is five feet. They are sociable animals, usually traveling in herds, and can often be seen sporting playfully. Indeed, the sight of these attractive creatures is familiar to nearly every person who has had occasion to sail the sea, for their distribution is almost world wide. The bottle-nosed porpoise (*Tursiops truncatus*) is the most numerous of those along our Eastern shores. It follows shoals of herrings, on which it feeds, and is frequently caught with them in the nets of fishermen. In the spring, when the herrings make their seasonal run, the occurrence of this porpoise in Hempstead Harbor is not uncommon. To me there is something majestic in the motion of this animal as it plunges forward, alternately rising to blow and disappearing gracefully under the waves.

The so-called "spouting" or "blowing" of cetaceans has not been the least of their curious attributes; and truly the spouting of a large whale is a spectacle never to be forgotten. It is not, as is commonly believed, even by many whalers, the discharge of water taken in through the mouth; it is simply the natural process of breathing. Bear in mind that cetaceans hold their breath for longer intervals than do land animals; therefore, in expelling it much greater emphasis is used. In rising to the surface, they forcibly rid their lungs of the air taken in with the previous inspiration, and this outrushing air is charged with water vapor due to ordinary respiratory changes; consequently, in the colder regions where the spouting is really more evident, the vapor condenses and forms a conspicuous column of spray. Now it often happens that the animal

will commence blowing just before it actually reaches the surface, and in that event some water is carried upward by the blast. It is quite possible, therefore, that this illusory effect has confounded many observers. The height to which the column ascends has also been subject to much exaggeration; in the very largest whales the spout does not exceed twenty feet at the highest.

Most whales as a rule are peaceably inclined and inoffensive; with the exception of the killer whale and one or two other doubtful kinds, the greatest danger from a close encounter with them lies in a chance blow from the powerful tail. A large individual can easily splinter a small boat into fragments with one sweep of its massive flukes, gravely endangering if not destroying the occupants outright. But for positive and prepotent danger to man, we must look to the sharks who in this respect take precedence over every other creature, great and small, which lives in the sea.

Although sharks are found in all oceans, they are the most numerous in the tropics. Since there are more than one hundred and fifty described species of these animals, it will become apparent to the reader that the group is not so small as is commonly supposed. They are gill breathers; hence they are true fishes. Some of the sharks bear fully developed young; others lay eggs. The eggs are large in comparison with those of other fishes, and each one is usually contained in a tough, horny, quadrangular case, the corners of which are prolonged into tendrillike processes apparently for the purpose of entangling the object in seaweeds. These egg cases are ofttimes carried by the waves to the

beach, and are popularly known as "mermaid's-purses." Near the head of the embryo a slit in the case allows the water to enter for its respiration, the water subsequently passing out through another slit at the opposite end. On issuing from its cradle the young shark ruptures the end near its head, and carries with it a yolk bag which it retains for nourishment until such time as it is able to seek food. Its respiration at this stage of its life is performed by the aid of filaments projecting from the gills through the gill clefts. As it gets older, which is to say, by the time it uses its teeth efficiently, these filaments and the yolk bag disappear.

What in most fishes which are familiar to us is a calcified frame—that is to say, a skeleton of bone—is in the sharks, a tough, or cartilaginous, structure. This shows that they are of a quite primitive nature, that they had their beginning long before bones were in evidence. But their claim to ancient ancestry is established in other ways than this; their remains are preserved in rocks much older than those which hold the fossils of bony fishes. From the abundance of teeth which are found in the older deposits, it is quite probable that the sharks were much more numerous in former times than they are to-day. They were also much larger; certain individuals of one genus (*Carcharodon*) being over ninety feet in length. There is one existing species of this genus (*C. rondeletii*) the members of which are thirty feet long, but it is nearly extinct. The abundance of sharks' teeth is so great, in fact, that some of the beds in which they occur are quarried to obtain the fossil remains for fertilizing purposes.

The sharks that habitually live near the shore are in the minority. They are of small size, and are usually known locally as "dogfishes." Although feeding on what fish they can catch, they are scavengers by nature, taking almost any animal food that comes their way. Some of the larger sharks of the open sea occasionally come close to shore, but their stay is only temporary as they merely make these visits in their hunt for prey. Many are armed with strong, sharp, cutting teeth with which they can do considerable execution among the porpoises and large fishes that they hunt; others, which are provided with very small teeth, feed only on the smaller fishes, and invertebrates. Nearly all of these oceanic types seem to be viviparous: in other words, the young are born the same as are those of mammals: they are incubated in the body of the mother, not hatched from the extruded egg.

It is among the sharks that effect the open sea that occurs the common white shark (*Carcharias vulgaris*), the most dreaded monster of the deep. The genus to which it belongs is a large one numerically and in respect to the length of some of the species. The individuals are generally recognized by their two large dorsal fins and flattened snout. It is not uncommon for the white shark to attain to a length of twenty-five feet or more. A tough, hard skin covers the body which is grayish brown above and white below. In the warmer seas where it abounds, it quite often follows in the wake of ships attracted by the edible parts of such refuse as may be thrown overboard. Not always does it confine itself strictly to digestible material, however; so voracious is it that often it will seize indiscriminately any

object within its reach. In the stomach of a white shark, it is said, was once found a woman's workbox; while the papers of a slaveship, which had been jettisoned, were found in that of another. This creature will not hesitate to attack humans, and it is capable of tearing off a limb or even severing the trunk. Numerous accounts have been given of instances where a man armed only with a knife has gone into the water and worsted a shark, usually a shore shark; but here is one beast which man has probably never braved in its own element; no one could successfully cope with a brute as huge as this and provided with such a terrible apparatus of saw-edged teeth. Still, it may easily be captured alive. South Sea Islanders are said to use a curious, though simple, device which consists of a floating log with a strong rope attached to it. At the end of the rope is a noose; and the animals gathering about from curiosity, one of their number usually succeeds in engaging its head in the trap, finally exhausting itself in trying to get free. Sailors catch this creature by using a great hook baited with a piece of meat. The hook is fastened to a chain, since the powerful jaws and teeth of the animal would bite through any ordinary rope with ease.

Perhaps just as common, and even as much to be feared, but considerably smaller is its near relative the blue shark (*Carcharias glaucus*). This shark is proportionately more slender, and is seldom over seven feet long. The upper part is blue; underneath, it is white. Although normally a dweller of warm waters, it often extends its range, for it has been observed as far north as Long Island Sound, apparently coming in

pursuit of herrings. It frequently plays havoc with the nets of fishing trawls, its sharp teeth cutting them to tatters. This is the "man-eater" shark so often figured in stories and tales of travel. Very likely its reputation is well deserved. It seems to be absolutely fearless. When it is captured with a hook and hauled on board, the utmost care is necessary in order to avoid serious injury from its mouth or tail. The deadly movements of the latter are generally interrupted by a sailor's

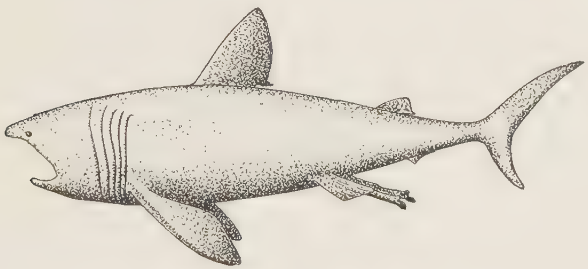
MAN-EATING SHARK.

springing forward and cutting the spine above the tail fin with an ax.

The Greenland shark (*Lacmargus borealis*) is the notable exception to the order. It inhabits the cold northern seas, and is rarely seen elsewhere. The two dorsal fins are small. In size it approaches that of the white shark, but its head and teeth are smaller. Nevertheless, its ability to use its jaws with effect is testified by many reliable observers. It is a truculent enemy of large whales, these having been frequently found with pieces bitten out of their tails by this animal. Whalers have reported that while a crew was occupied in cutting away the blubber of a killed whale, a Greenland shark

approached the carcass and tore off piece after piece, and even after being badly wounded by them it persisted in returning to the repast.

But—enough of the ill-reputed sharks. Now a few words regarding one of a very different type. This is the basking shark (*Selache maxima*), the largest of them all—and, by the same token, it is the largest living fish. It grows to a length of more than thirty feet. The width of its mouth is extraordinary, thus giving it an appearance of unusual ferocity. Yet, notwithstanding its terrifying size and forbidding aspect, it is quite innocuous. As a matter of fact, the creature is of a very timid disposition, and will readily retreat if approached too closely.



BASKING SHARK.

What is the reason for this remarkable behavior? The answer lies in its teeth. For a shark, they are amazingly small, and it is very probable that they serve no purpose whatever. The fish and other creatures it lives on are diminutive in size, and are such as would cause a regular man-eater shark to turn up its snout, so to speak. As large as is the mouth of this animal,

it is capable of greater expansion, and with a single gulp it can capture a prodigious number of these animals. Now, naturally, with the food that it takes in, a considerable quantity of water is engulfed. The provision for the retention of this food and for the escape of the water is as singular as that of the whales. In each of the very wide gill clefts which this shark has, the internal opening is guarded by a sort of strainer, an apparatus formed by the hard supports of the gills. It is this sieve which allows the water to pass out of the mouth while holding in the organisms. Thus, in a sense, the creature may be said to take in its food at a breath.

As its name would indicate, it loves to lie in the sun. It lives in the North Atlantic, and there it may be seen in calm weather collected in companies, with broad fin erect, basking motionless at the surface.

Chapter XVI

LIVING LIGHTS THAT NEVER DIE

The impressions of youth are most profound—likewise its illusions. The gentle breeze from over the harbor coming through the open window to my writing table, the stillness of this early hour, the stars seen suspended in the outer darkness, like sparkling motes of metallic dust, all bring out in realistic relief the details of an event now remote in time, in distance, and in the potentiality of its circumstances, but one which has to do with a type of creature I presently propose to consider. I once stood near the rail of a ship sailing a tropical sea. It was night. There was no moon, but across a glittering sky hung the luminous mist of the Milky Way, while standing out sharply above the faintly limned horizon could be seen the silvery radiance of the Southern Cross. The reflection of that ghostly stream and of every scintillant point shone without a tremor on the unbroken surface of the watery expanse like spangles on a field of sable velvet. Steadily the ship pushed ahead, yet seemed to remain motionless over that vast inverted image of the celestial panorama. The dull throbbing of her engines deep down in the waist, and the swift swirling of the waters below the forecastle head, where I was stand-

ing, as her sharp prow cut into the blackness, were the only sounds that lifted themselves in the profound silence of the night. Peering over the side, I beheld the foam streak past in the gloom. It was all aglow, as if the boat in her progress had stirred the water into a seething billow of molten glass. And far astern followed the wake of the vessel—a livid path of sulphurous light. Like a meteor lost in the mighty reaches of the cosmos, she seemed to be traveling through space, marking her course with a fiery trail.

Then came a change. A light wind arose and the sea ran in ripples of fire. Coruscations of emerald and azure and pale orange played over the radiant crests; and the spray caused by the buffeting bow fell into the sea like a shower of shining sparks. Dissolved from the face of the water was the reflex of every star. The galaxy no longer loomed as a tremendous vapory swing in the solitudes of the deep. Instead, as far as sight could penetrate, the trembling surface gleamed and flamed with a light of a far different kind; and the colorful intensity paled even the brilliant spectacle of those mighty suns that shimmered in the midnight sky.

What could be the nature of that mysterious light? The impulse to examine the water more closely was irresistible. So, tying a rope to the bail of a bucket, I lowered it over the ship's side. But I was not prepared for such a pull as I felt when that receptacle met the surface, and was nearly jerked over the rail and into the sea. The speed at which the boat was going made it seem as if the bucket had caught up a load of melted lead. However, I did not let go (the rope was new and of considerable length—therefore, valuable—

and buckets on that ship were scarce; besides, I did not fancy an explanation for the loss, which would be certain to invite a suspicion of my sanity), but managed finally to bring up the bucket with its luminous burden. Setting it on the deck, it stood out clearly in the surrounding darkness. By the glow of its bluish light, I could easily see the freckles on my hand. Dipping some of it up in the hollow of my palm, the escaping water fell to the deck in sparkling drops and ran in shining rivulets along the seams. Yet I could detect nothing therein that gave it this remarkable and mysterious property. Looking as closely as I could, I saw little patches of pulsating colors, which swiftly increased in brightness and then as swiftly died out again somewhat like the embers of a fire revived to topaz brilliancy by the passing breeze, and that was all. I emptied the contents of the bucket overboard, and remained for many minutes with my attention on the waters below, watching and wondering. But the sea did not vouchsafe its answer at that time. Indeed, little did I think, as I stood there, stripped to the waist, grimy, and still sweating from my turn in the hot stifling air of the stokehold, that later I would be revealing that and other secrets of the sea to curious readers. It was my first voyage, and I had never seen the ocean before. My knowledge of it was limited to what I had read in stories of adventure and travel, while living in a mid-Western hamlet. Of its animals I knew nothing, save what every boy knows regarding the creatures which are often called upon to lend color to the exploits of fictional heroes. No, at that time my dream was that I, too, would write the selfsame manner of tales

that had lured me to the sea. Such are the illusions of the young! Here am I, not engaged in romancing about the ships and men that sail the surface of the sea, but in detailing the lives of the lower creatures that range its depths.

The nightly phosphorescence of the sea—which was the phenomenon just described—is as familiar to the traveler in the tropics as are the flying fish in the day. Yet not everybody knows that this is caused by the presence of billions upon billions of little animals each so minute as often to be scarcely visible to the naked eye. There are a number of forms which may produce this amazing spectacle, but the largest here is much smaller than the head of a pin. This one is Noctiluca, the most numerous and most widely distributed of all the light-producing creatures of the sea. In general, its shape may be likened to that of an apple whose stem is drawn out into a whiplike lash. It is with the aid of its large lash, or flagellum, that the tiny animal drives itself through the water. In structure, it is transparent and jellylike, and the entire organism consists of but a single cell. Now, this animal, small as it is, lives upon other organisms still smaller; and under a powerful glass, it may be observed to take in its food, selecting such things as are suitable in the surrounding medium, showing that it has its likes and dislikes the same as higher creatures whose bodies are composed of millions of cells. Its mouth is situated at the base of the flagellum, and is a groovelike orifice extending nearly halfway around one side. From the mouth issues a small hair-like organ, a second flagellum. The little spherical unit, like all cells, is made up of three principal parts:

the *nucleus,* which here is a small granular kernel near the center; the *cytoplasm,* or cell substance, and the cell wall. From the nucleus can be seen radiating through the cytoplasm a number of branched granular threads. This simple structure—that is, the fact that Noctiluca is a one-celled creature—places it in the very lowest group of animals, the *Protozoa.*

NOCTILUCA. (GREATLY ENLARGED.)

In common with other protozoans, Noctiluca does not die from old age; in fact, barring bodily injuries or other accidents, it does not die at all. The reason for this can best be understood by examining its mode of reproduction. When the individual reaches a certain stage in its life, a division of its nucleus takes place which is soon followed by a constriction in the cell wall right around the middle of the animal. This constric-

tion rapidly grows deeper, finally separating the creature into two equal parts, each part a smaller but exact duplicate of its single prototype. Thus where there was one adult mother cell, there follows in her place a younger pair; and these twin daughters will in their turn, when they get older, proceed to divide likewise. In this manner the cycle continues. But it may be pointed out that this method of reproduction by fission, as it is called, does not always continue indefinitely without a variation. During some succeeding generation two individuals will come together and a fusion of their nuclei will take place, the flagella disappear, and the pair seem to coalesce into a single body; reversing the process of division, so to speak. Eventually, however, the fused nuclei split into numerous pieces and pass to the surface of the sphere where they form prominences, or buds, which ultimately become detached and swim away as zoöspores, or young Noctilucas. When these grow up they will divide, and their descendants for a greater or lesser length of time will also continue to reproduce in this way.

The color of light emitted by Noctiluca varies with the different species; still sometimes a single species will be found to give forth light of different hues. The beauty and intensity of the flashes are marvelous, coming from so small a creature, and their nature has been the subject of much investigation. But man has as yet vainly endeavored to capture its secret. He has, indeed, been able to isolate the chemical compounds which are the source of light, and has even given them a name, but of their ultimate nature he is still very much in the dark. The term "phosphorescent" ap-

plied to light-producing animals owes its reason to the fact that the illumination resembles the glow of phosphorus, but, in reality, it has nothing to do with that element. Phosphorus, in its free and luminous state, is highly poisonous to all living animal substance.

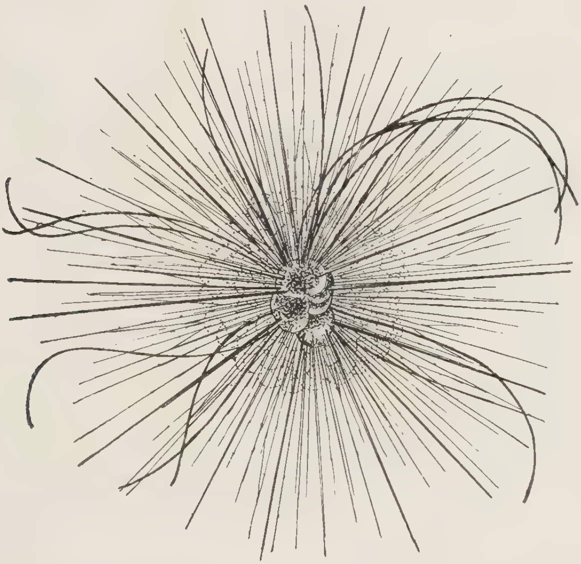
Contrary to popular opinion, the peculiar property of phosphorescence is by no means a rare one or confined to a narrow range of animals. The fact is, in the animal kingdom, in groups extending from the protozoans to the vertebrates, there are more than three hundred genera containing one or more species which are known to emit light. The majority live in the sea. Of these, Noctiluca is the best known, but it is not the most intensely luminous. That distinction goes to a little ostracod crustacean bearing only the Latin name *Cypridena hilgendorfii,* because it is known to few others than naturalists. So powerful is the light from this creature that one part of its luminous gland in nearly two billion parts of water will give a visible glow to that medium. If a person possessed an organ that gave the same proportionate volume and intensity of illumination, it would be sufficient to light up the area of a fair-sized city.

In the light of Noctiluca, experimenters have discovered two very interesting properties. It has no heat, and it has no light rays that are invisible to the eye. The bolometer, a heat-measuring instrument so sensitive that it can register the heat from the stars, has revealed—as, in truth, it has revealed in the case of all light-producing animals—that the phosphorescence is utterly without warmth, that it is what is called "cold light." My statement about the light rays may need

elucidation. It is well known that a beam of ordinary sunlight actually consists of several different colors which can be shown on a screen by first passing the beam through a glass prism. This color picture is called the spectrum and is composed of visible hues ranging from deep purple through the blues and the yellows to deep red. If, by some suitable arrangement, a photographic plate be placed at the plane of the screen, excluding all other light, an image of the color picture will be recorded. But, in addition to those colors which are visible, there will appear on the plate a record of colors which are invisible to the eye. These colors are at each end of the spectrum, and are known as the infra-red and the ultra-violet rays. No artificial light has yet been devised which eliminates all of these invisible rays. Now, as the light of Noctiluca does not contain them, it will be seen that its illumination is about one hundred per cent efficient, no light-producing energy being lost. However, what value Noctiluca—and, indeed, many another sightless animal which could be named—derives from its power of luminescence is not clear. It is probable that in this instance phosphorescence is an incidental manifestation of some fundamental cause which has for its end not the production of light but something much more remote from our comprehension.

So thickly populated with protozoans is the sea that hardly a drop of water collected near the surface will fail to produce numerous individuals. They are, of course, not all light givers, like Noctiluca; but what they lack in this respect they often make up in exquisiteness of form. Many of them secrete shells, and al-

though some giants measuring more than an inch in diameter are to be found in the warmer waters, most forms are so small as to be practically invisible. A wonderful work is performed by these shells in building the crust of the earth. They are constantly settling to



GLOBIGERINA; A PROTOZOAN. THE SHELL OF THIS MINUTE ANIMAL IS IN THE CENTER, AND FROM IT RADIATES STIFF SPINES OF LIME. ENCLOSING THE SHELL IS A FROTHY MASS OF LIVING SUBSTANCE FROM WHICH EXTENDS NUMEROUS FINE THREADS.

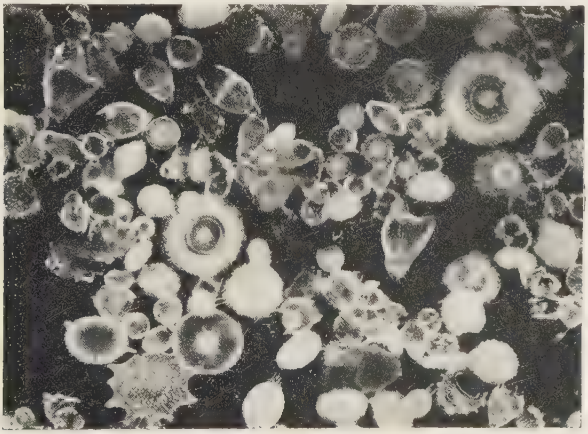
the floor of the ocean. The dead shells are almost the sole constituent of the material that forms the bottom in many regions of the deep sea. They also compose the platforms of coral reefs. The famous chalk cliffs of England are made up of their countless billions which long ago were dropped upon the floor of the

ancient sea, piling so high that some in the lower layers were squeezed into a shapeless mass; then by some later convulsion they were lifted out of the water high into the air.

The numbers which float in the sea are utterly inconceivable. The only proper estimate we can make of them is not to count them but to weigh them. It is supposed that these minute creatures are as abundant six hundred feet below the surface as they are at the top; therefore, taking this as an index, it has been shown that within this depth alone, every square mile of the ocean contains upward of sixteen tons of their skeletons. And this is to say nothing of the countless other forms which have no shells.

In some of these creatures, the foraminifers, the skeletal structure is composed of lime; in others it is formed of silica, a transparent, glasslike substance as hard as flint. The latter type is peculiar to the radiolarians, without a doubt the prettiest of all protozoans. The almost endless variety of forms is a constant source of pleasure to the collecting microscopist, for in no other group of minute organisms does beauty so consistently prevail. Many are globular and perforated, and the soft body substance of the animal can be seen streaming through these apertures for food. Some are like fairy baskets formed of the most delicate latticework; some perforated spherical forms bristle with long, slender, flinty spines; and some others still have a crystallike sphere within an outer lacelike covering of glass, resembling those curious balls of jade, carved by the Chinese, wherein one graceful creation contains another still more lovely.

The foregoing facts in this chapter convey some idea of that stupendous abundance of animal life contained in the sea, whose beauties and even whose very existence are barely known to the world at large. But my mentioning the coral reefs prompts me here to add something in regard to another type of small creature, which, notwithstanding the world-wide acquaintance with its



SHELLS OF RADIOLARIANS. (GREATLY ENLARGED.)

skeleton, seems little known as it is in life. All corals, by the way, are not confined to the warm waters of the tropics. Some colonial forms are found on our western coast, and certain kinds grow in the Atlantic as far north as Long Island Sound, where the water is often icy cold. Solitary species, like Fungia, flourish in the cold water of very great depths.

The reef-building corals are of a different character. They are rarely found below a depth of about one hun-

dred and seventy-five feet, and never do they live in water the temperature of which is less than 68° Fahr. In the tropics their great reefs extend for miles and assume countless curious shapes, sometimes spreading out like a fan, or branching in every direction, forming figures and heads and limbs. This is characteristic of the Tortugas Keys off the coast of Florida, but among the coral reefs of the Pacific they form great circles, or rings, called atolls. Many reefs are exposed and flourish with vegetation, and the charm, the beauty, the loveliness of these verdant isles can be realized only by those who have passed them at sea.

It is a curious fact that although corals have been familiar objects since very ancient times, their animal nature was not known until the eighteenth century. The discovery was made by an amateur naturalist who had succeeded in keeping some specimens of red coral alive in a tank. His discovery, however, was rejected by the professional men of science, and it was not until nearly twenty-five years later that they were compelled to recognize the truth of his claims.

The coral animal is a cœlenterate, a polyp. It resembles an anemone with the difference that it has the faculty of taking lime, probably from the water or from the food it eats, and secreting it in the chambers of its body, where it, the lime, forms partitions or cells, as the case may be. Although they live in colonies, unlike hydroids, each coral polyp is a complete individual in itself, having no physical connection with its neighbors other than the dead skeletal remains on which they make their home. The home of each individual is called the *corallite,* and a group of these corallites, such

as make up a branch of coral, is called the *corallum.*

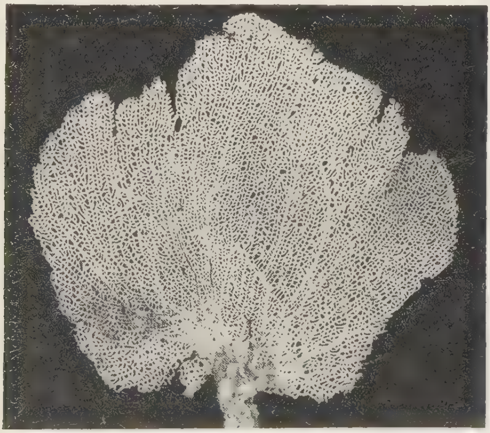
Corals reproduce by eggs, by budding, and by self-division. It is, in fact, due to the way in which budding or division takes place that the characteristic shape of the corallum is formed in the various species. In branched corals, the budding is confined to certain members of the colony, which results in that beautiful type; but the formation of so-called brain corals is caused by the process of division. Now if we followed the development of a growing coral, starting with the free-swimming egg, we should see it attach itself to a stone or some hard object and commence first to build a little platform or base. Then a thin edge or rim would rise around the periphery, increasing daily in diameter and height. At the same time, though unseen, the growing creature is building within the corallite a number of partitions that extend from the cuplike rim toward the center but do not meet. If the corallite be cut across, the lime that forms the rim and radiating partitions will have a rough resemblance to a cart wheel with the hub removed. The vacant area in the center contains the polyp's stomach. When full grown the soft tissues are an olive brown, and with its expanded tentacles looks like a tiny flower. If it should be a corallite of a branched coral, a bud will eventually appear on its side and the growth of an additional cup will take place. These growths will proceed until the enlarging coral branches out by further budding or by the division of the individuals. Growth is fairly rapid. Branch corals will grow seven or more inches in a year, and the brain coral has been known to attain to an inch or double its size in that time. Yet the reefs that they compose do

not progress on any such scale as this. For although they are called reef builders they do not in any way erect a permanent structure as living animals; it is their skeletons, compacted in solid masses, but containing material wrought by other agencies as well, that make the reef. And it is very probable that the accretions do not cause it to rise more than an inch in twenty years.

One of the factors causing the solidification of a reef is the work of the horde of other organisms which inhabit it. Such animals as crabs, mollusks, and sea urchins reduce and perforate the coral by scraping and boring and so weaken it that it breaks away in fragments; these are in turn ground to sand by the continual washing of the waves, thus filling the interstices of the reef. Many wonderful fishes and other creatures, garbed in brilliant tints, make their homes in these stony forests, and the picture they present in the clear blue water of the quiet lagoons, poised among the branches, is one of the rarest offerings of nature. Occasionally one of the branches will have a group of large polyps, each half an inch across, the whole resembling a spike of pretty flowers. The colors of the corals, too, are various and pleasing. Some have red, white, or green polyps on branches of red or of brown. Others may have their whole mass tinted pink or lemon or bright blue.

Often in the same waters with the reef builders, grow live corals of another type so different in appearance and structure that few persons would be likely to take them for corals. These are the sea fans and the sea pens and the curious organ-pipe corals. They do not always solely secrete lime like the madrepores (*i.e.*,

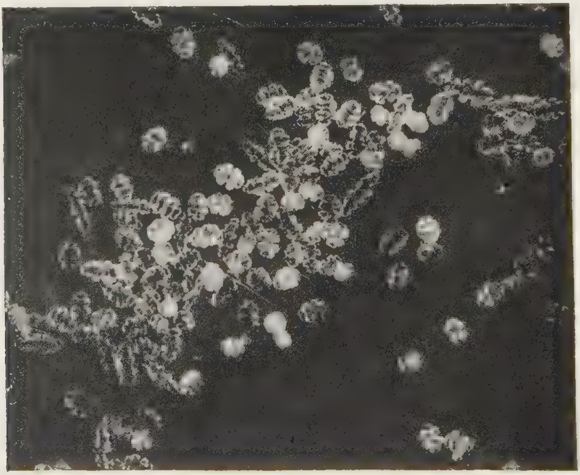
brain corals, branched corals), but instead they sometimes form their framework of a more flexible material, the chief constituent of which is chitin, the horny substance that composes the wing cases and hard parts of beetles and many other insects.



GORGONIA; A SEA FAN.

On the mud flats and coral reefs of Florida, and the reefs that form the keys, can be seen the sea fans growing in vast fields, strange, exotic, and colorful. Technically they are known as Gorgonias. They are colonies of polyps having a calcareous or horny skeleton branching profusely in one plane. The branches are often fine and run together, forming a network of great intricacy. Some of these structures are several feet in length and in breadth, and are in the shape of an enormous fan. Certain varieties of Gorgonias resemble branching shrubs; and the shapes of others are rodlike,

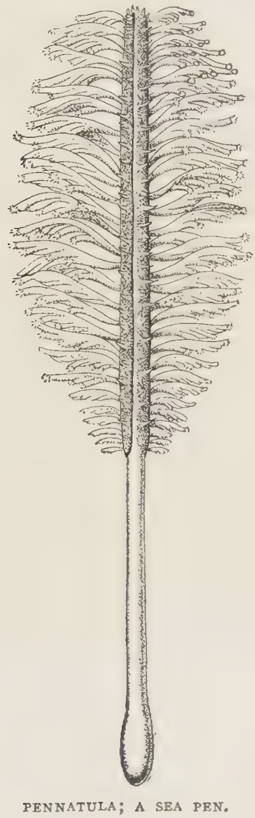
long, and without branches. Still others are unbranched spirals, several feet in height. These are sometimes known as sea whips. In all Gorgonias the horny axis is covered with a layer of living polyps so closely united that they form a solid sheet of animal matter. This contains numerous small spicules of carbonate of lime, giving it a barklike, or crusty, appearance.



SPICULES OF GORGONIA. (GREATLY ENLARGED.)

The sea pens are so named because many of them look very much like the quill feathers that are used for pens. Some of the species resemble ostrich plumes. The polyps are arranged along the upper part of the lateral branches, separate from one another. The central axis is naked below, and this part is buried in the sand. Some sea pens are capable of great expansion

and contraction. A specimen measuring about five inches, when taken from the deep water, was observed



PENNATULA; A SEA PEN.

to expand five times as large when placed in a tank an hour later. It was of a delicate pink by day, and by night it shone with a brilliant phosphorescence, the light

flashing from branch to branch, and polyp to polyp. Nearly all sea pens are marvelous light producers.

Among the corals of the East Indian seas is to be found the most peculiar, perhaps, of all, the organ-pipe coral. Its structure is very fragile and the cells of the polyps are arranged after the fashion of a pipe organ, from which it takes its name. The red tubular compartments are separated from one another, but are connected at intervals by horizontal platforms. The polyps contained in the tops of the tubes are green, and save for their color, they resemble miniature daisies when expanded.

The corals form much of the framework of the globe. The great barrier reef of Australia is over a thousand miles long, and in nearly every part of the world are found the fossil remains of reefs. One underlies a section of the State of New York and is in a way as interesting as that which now reaches out from Florida in the direction of Yucatan. For in its history is entailed the thrilling story of our continent, the story of an era when our waters were much warmer than they are to-day.

Chapter XVII

INTO THE DEPTHS

No one has yet been able to penetrate in person the abyssal depths of the ocean, yet we have means of knowing that those regions support a strange and wonderful life. Nearly all parts of the sea have been sounded; many areas have been dredged; consequently, our views as to the relief of the floor and the types of animals associated with it are gradually becoming clearer. Of course this does not mean that we are acquainted with the habits and histories of those animals; those things probably will take many years to obtain, if, indeed, such a thing is possible at all; but from the facts already collected, it would not be hard to guess how some of them live. When the vast extent of the ocean is considered, the number of soundings seem comparatively few, and for that reason it has often been pointed out that our knowledge concerning the depths is very fragmentary and limited. In a sense, this is true. On the other hand, if the extent of the ocean be great, the uniformity of conditions over vast areas is likewise great. A law seems to prevail that the deeper one goes, the more identical are the species. If one could walk around the world on the bed of the ocean, he would find the same type of animals. The

main cause regulating this is temperature, which in all seas is the same after the depth of a little more than a mile.

The deepest place yet discovered in the ocean is the Philippine Deep which has a depth of six miles. Some conception of this terrific depth may be obtained when I say that it could contain Mount Everest, the highest mountain in the world, and still submerge it with more than a mile of water over the top. The term "deep" is one applied by marine naturalists to those parts of the ocean that are shown by soundings to be 18,000 feet or deeper. There are known to be about sixty of these deeps. Depths of more than 24,000 feet have been recorded in ten of them, two of these abysses being in the Atlantic and the remainder in the Pacific. Between the dry land and the various deeps exists a well-defined area known as the continental shelf, a comparatively shallow region, constantly swept by tides, waves, and oceanic currents to a depth of 600 feet; and it is separated from the deeps by an abrupt declivity, where the depth of the water increases rapidly, called the continental slope. No doubt many portions of the continental shelf were, at no very remote period, regions of dry land; for crossing it in numerous places are deep ravines that are believed to be submerged river valleys. In some places their connection with still existing rivers can be traced.

In the abyssal realm, wave action no longer makes itself felt, the oceanic currents are absent, and the water is still and cold—almost freezing—and utterly without any light from the sun. The darkness is relieved only by the light of phosphorescent animals. The enormous

pressure of the water—over three tons to the square inch—must make motion of all kinds extremely slow; and such fishes as are found living there are adapted to withstand this environment by having bodies so soft and delicate in structure that when brought to the surface they cannot be touched without injuring them. Plant life, except, perhaps, bacteria or other low fungoid forms, is entirely absent. The composition of the floor is made up of the material that filters down from above; these deposits, of course, varying according to the nature of the organisms at the surface; thus, where those protozoans known as Globigerina prevail, the ooze at the bottom is composed of carbonate of lime; where organisms which secrete silica abound, we find the floor underneath consisting of radiolarian or diatom ooze. However, in the very deepest parts of the ocean the calcareous organisms are removed by solution, and in some places siliceous remains are partly removed. In certain regions of the South Pacific Ocean far removed from the continental land, naturalists have brought up in their trawls hundreds of sharks' teeth and numerous ear bones of whales, some of which belong to species now extinct. Chondrites, too, which are found only in meteorites, and, mixed with the clay, magnetic spherules of metallic iron and nickel, and tons of manganese nodules were among the hauls. This abundance of teeth and bones and extraterrestrial objects in those remote depths is owing to the fact that few other materials reach those regions to cover them up, as in other deposits. From this may be gathered some idea of the slow rate at which the floor deposits accumulate; probably not more than a foot since the

time that the gigantic reptiles roamed the earth. Over and above this, it appears from these indications that of all portions of the earth's crust, the centers of the great ocean basins have remained the most stable since very ancient times.

It was once believed that as deep-sea explorations became more extended, the unknown depths of the sea would reveal some survivors of an earlier geological period which would fill some of the gaps in the known pedigree of the animal kingdom. But in only a few instances does this expectation appear to have been realized. The numbers of deep-sea species which have been discovered are very great, yet, generally speaking, they are not unlike the forms that inhabit the shallow waters or else they have adapted themselves to their changed conditions of life by special modifications of their structure. In fact, it is not easy to point out any fundamental feature wherein the deep-sea animals differ from those of shallower waters; what differences do exist are of degree rather than of kind. Therefore, it is thought that because the animals of the deep sea resemble those living in the shallow water at the present time, rather than those of a former age, the abyssal creatures may have migrated to where they now are at some era not long passed, comparatively speaking. Nor has this migration ceased. There are indications that the exodus from our shores, though gradual, is as marked to-day as at any time in the past.

Yet, notwithstanding that the animals found in the deep sea are as a whole not of a primitive type, certain ancient crustaceans seem to have been harbored there since times remote, or, what is more likely, they sought

the refuge of those cold, unlighted haunts as the last resort from the too strenuous competition imposed by the parvenues of the thickly populated shores. One form is a family of lobsterlike animals (*Eryonidæ*) which have fossil representatives in some very old rocks; another is a group of crabs (*Homolodromiidæ*), which seem to be the most ancient of the existing brachyurans. It is also quite probable that certain prawns (*Penæidæ* and *Acanthephyridæ*) found there are of an older type than their shallow-water relatives. Then, there are the Crinoids, or sea lilies. Their history, too, is written in stone. They are often called stone lilies on account of their close resemblance to the lilies of the land. They are not plants, however, but are related to the starfishes. The long-jointed calcareous stem is supported in the ooze by rootlike branches, and the top is capped with what has the appearance of being an inverted starfish; literally, this is a starfish sustained by a stem. Crinoids have existed from early geologic times, and apparently were once the only class of echinoderms; traces of their evolution into other forms can be followed to some extent through successive geologic periods. Their fossil forms are very abundant, showing that they once thrived in enormous numbers. The fact of their present existence is a modern discovery, for, although their fossils had long been familiar, no one was aware that there were living descendants until the deep sea was dredged. But they are dying out, there now remaining, perhaps, not more than twelve of the two hundred genera which are known to have formerly inhabited the sea. One bed of Crinoids lies off the coast of Cuba; but

a field of particularly fine, large specimens is found in the waters of the Pacific near Japan. The form rep-

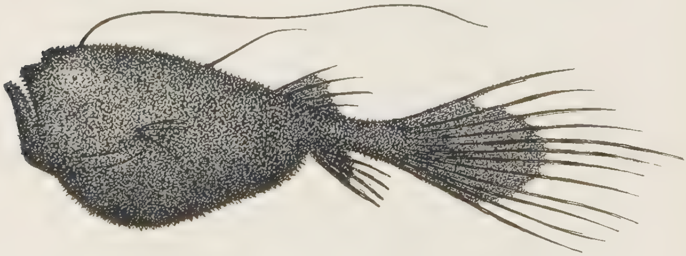
THE STONE LILY; A FOSSIL CRINOID WHICH LIVED IN AN ANCIENT SEA.

resented by the genus *Pentacrinus* remains permanently fixed, but the *Comatula* form separates from the stem at a certain stage in its development, and swims

THE SEA LILY; A LIVING CRINOID.

about by means of its arms. Tubular processes growing on its body at the point where it detached itself enable it to fasten itself to other objects for support.

As a rule, the individual colors of the animals inhabiting the depths are uniform in tone. Stripes and patterns, such as mark the creatures of the shore, are conspicuously lacking; in those Cimmerian solitudes there is little need for colors that warn or hues that hide. The echinoderms range from yellow through orange and red to purple, while the crustaceans are



CERATIUS; A FISH WHICH INHABITS THE DEEP SEA.

mostly crimson or pink. Fishes are generally black, and nearly all of them are phosphorescent. Many of the animals are blind, as if they had long ago abandoned the effort to see; their organs of touch are often highly developed; and they probably lead an inactive life, burrowing in the soft ooze or clinging to sponges and other low fixed forms.

Luminous fishes have, most of them, excessively large eyes, seemingly adapted to catch the faintest ray of light; and it is probable that these apparently more active and predatory types are guided to their prey by

its own light, or seek it out by the aid of the light that they emit themselves. The luminous spots or lanterns of many fishes are developed in such a way that the animals can use them to light their way in the dark depths, and in some forms these shining organs serve as veritable searchlights. For instance, in one (*Æthoprora*) the end of the snout is covered with a phosphorescent appendage that directs the light like the headlight of a locomotive; another has a pair of great flat eyes covering the whole top of the head, and the eyes themselves are luminous. Of these predatory creatures, many have enormous mouths and monstrous-looking teeth, giving them not only a frightful, but a fantastic appearance. And, indeed, some have been known actually to swallow creatures larger than themselves. This seemingly impossible feat is owing to the great distention that their soft tissues can effect. Also, their vertebræ lack specialization, and as a result their bodies are elongate, showing more or less degeneration in those characters usually associated with surface environments.

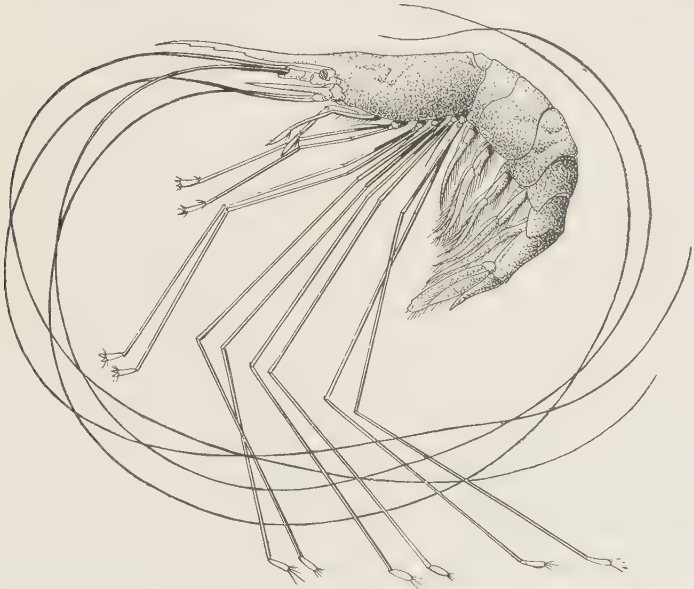
Although, as I have stated above, the color of deep-sea crustaceans is usually crimson or pink, there is much variation in the range of these shades. In truth, they are very curious in this respect. The blanched appearance that we might expect of creatures living in perpetual darkness, such as is known to distinguish those inhabiting caves, is relatively rare. More frequently, their colors, though uniform, are vivid, and, in some cases, even approaching brilliant orange. In some way not understood, the red color is associated with the darkness. This has been shown by experiment.

Green crabs, when kept in partial darkness, turned brown; these, when kept in total darkness, turned red. On this account it has been suggested that the colors of crustaceans may be taken as an index to the depths in which they naturally belong. Thus, those of a pale hue find life more enduring when farthest removed from the sunlight; while the pink, red, crimson, and, finally, purple, blue, green, and heterogeneous forms are normal for each succeeding higher level. But this supposition cannot now be accepted without considerable modification. And to speak of a bathymetrical (depth-level) succession of colors in crustaceans would not be quite true.

Deep-sea crustaceans which rest or move about on the soft ooze of the bottom indicate by some very obvious peculiarities of structure their manner of overcoming the difficulties of that mode of life. The crabs are mostly long-legged or spiderlike; and in a number of instances the legs are fringed with long stiff hairs, and others have spines on the body and legs, all of which may prevent them from sinking in the yielding ooze. The extremely long, slender legs of certain prawns are undoubtedly used as stilts by their possessors when making their way over the floor.

Since the temperature is constant and uniform throughout the world at certain depths, this renders it possible for many crustaceans to live in the tropical deep waters, which are identical with, or nearly related to, the shallow-water species of the colder seas. Hence, lobsters have been found in comparatively deep regions of the Indian Ocean which were very closely allied to a species known to occur along the shores of Norway.

This to some extent explains why we find many similarities in the species of marine animals inhabiting the regions at the opposite poles of the earth. Certain families, genera, and even species have been observed in both the Arctic and Antarctic seas, yet they seemed



NEMATOCARCINUS; A DEEP-SEA CRUSTACEAN.

to be entirely absent in the intervening tropical zones. But when the latter depths were dredged, some of those forms were found; the low temperature of the deeper water offered them a connection between the North and South.

In the deep sea is found that very singular family of

hermit crabs, the *Pylochelidæ*. I have elsewhere in this work shown by internal evidence that the little hermit crab, Pagurus, of our shores, at one stage of its evolution was the possessor of a lobsterlike hind body. Well, here, in this deep-sea form, is one whose hind body is segmented, perfectly symmetrical, and shows no indication of ever having acquired the habit of living in gasteropod shells. The truth is, these forms are so primitive that it is somewhat difficult to find many features by which to distinguish them from the true lobsters themselves. No fossil representatives of the hermit crab have yet been found; there can be scarcely any doubt that the Pylochelidæ are closely connected with the primitive stock from which other hermit crabs evolved. After all, what seems most remarkable is, not that the abyssal crustaceans—and all other deep-sea animals, for that matter—are dissimilar to those of shallow water, but that they differ so slightly. Certainly, it should seem from the physical conditions prevailing in those great depths, the freezing cold, the inky darkness, and the stupendous pressures, that their reactions would be strikingly different from those of creatures inhabiting the shallow water; but, strangely, the differences of function are in very numerous instances accompanied merely by the most trivial differences in structure.

From the fact that some of the free-swimming crustaceans of the deep sea have been found at, or near, the surface, it has been supposed that they may do so for the purpose of spawning, which is not unlikely, considering the sensitiveness of young animals to cold; but, as shall later be pointed out, other urgent factors bring

them toward the top. If, as it appears, those forms remaining permanently on the bottom originally came from near the shore, and the swimming forms descended from ancestors who swam the surface reaches, it may be that the young of the latter types still find in the surface ancestral conditions favorable to their development. Nor is the fact that they may come for this purpose in any way remarkable. The toad returns to the water to spawn; the land crab goes to the sea; and the eel goes back into its ancient habitat, the salt water, out of regard for the welfare of its young. It is noteworthy that in many of the deep-sea crustaceans, the eggs grow to an enormous size before they hatch. From this, and from what we know of the development of the crayfish and certain land forms, it would appear that the young are born at quite an advanced stage, ready to lead the same life as that of the adults. In this connection occurs a curious thing. Blue and green colors, although not uncommon among shore or surface crustaceans, are almost never seen in the species inhabiting the deep water. Yet the eggs of a large number of red deep-sea crustaceans are of a brilliant blue and often green. It is thought from this, therefore, that the blue pigment, common in the more familiar forms living at the top, is not actually absent in the deep-water representatives, but merely masked by the expansion of the red cells under the influence of their dark surroundings.

The feeding habits of deep-sea animals in general have always been a matter of much speculation. They are of necessity carnivorous; but in the absence of vegetation, and all that it entails, it is clear that they could

not continue mutually to subsist on one another indefinitely. One source of food supply is in the rain of dead organisms constantly descending to the bottom; and in the material thus settling upon the floor, the creatures burrowing in, or crawling over, the ooze no doubt find sufficient for their needs, and they, in turn, may serve as food for others. But there is not enough derived from the source just mentioned to benefit the whole of those myriads that swim the intermediate depths; so they must obtain it elsewhere. As a matter of fact, food is relatively scarce at the bottom of the deep sea, and for that reason only small forms can live there. Huge fishes and other gigantic creatures such as are associated with the surface are unknown in the depths, because there is virtually nothing there for them to eat. It was only recently that the great feeding ground, so to speak, of the swimming forms in the deep sea was discovered. It is near the surface. Strange as it may seem, these creatures, though delicately built to withstand pressure, are able easily to come to the top, and they do so at night. When the sun goes down, a great upward migration takes place; and during the darkness of the night, within a hundred yards of the surface, this hungry host can be found fighting and feasting amidst the plenitude that populates the top. With the breaking of the day, they return; for they are afraid to face the sun; in the battle with the abyss, they lost those weapons that would secure their safety in the light.

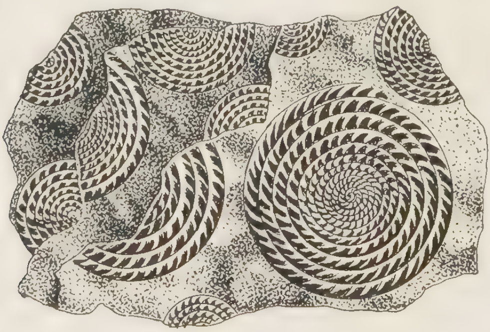
Chapter XVIII

LIFE IN THE ANCIENT SEAS

What traveler has stood before the pyramids of Egypt without having been thrilled by the thought of their hoary age? One's first sight of these mighty monuments is invariably accompanied by a feeling of deep awe, by the tremendous consciousness of their having endured since a time so remote in the affairs of man that only the haziest history of their builders remains. Nor is the significance of their antiquity lost on those who have never seen them. Through printed books, their forms have become familiar to all; and few that read have failed to feel the majesty of their years. Throughout those many centuries that witnessed the ascent and decline and disintegration of one of the greatest empires the world has ever known, that saw the rise of rude and barbaric peoples to nations of the highest culture, they have stood mysterious, seemingly immutable, marking the passage of time.

And yet the years that have passed since those piles were erected are but a breath in the bosom of geologic time. Consider. If a small section of the stone from which they are constructed is put under a lens, it will be found in many cases to consist almost entirely of little shells. These shells are of considerable beauty,

and are the products of very ancient animals called nummulites. Nummulites were protozoans, and they lived in the sea; the shells they secreted were coinlike in shape (hence the name). Internally these have a spiral cavity divided by partitions into numerous chambers. They seem to have no external opening, but the chambers communicate with each other by small perforations. Now the nummulites became extinct a long time ago; so long ago, in fact, that the earth has since



NUMMULITES.

been populated with other creatures, many of whom in their turn have died out too. So it will be seen that ages before the pyramids were built, perhaps before there was dry land where they now stand, these minute creatures were at work making the material out of which those structures were finally formed.

It is by the fossils we find in the rocks, of course, that we know what lived in the ancient seas. We also have means of knowing what rocks are oldest; therefore, we are guided by the creatures they contain in forming an

idea of what types successively dominated the waters of our globe. It should be borne in mind, however, that all reliable evidence we have of ancient animal life is in the nature of skeletons or other hard parts which have been retained more or less intact or have left their imprint in the rocks. Undoubtedly, there have existed numerous forms whose bodies were so soft throughout that they left no trace whatever. And doubtless, too, many hard creatures lived whose parts have not been preserved or which have not yet been found. Indeed, when we come to study the land surfaces and the sea floors of the present time, it becomes quite obvious that there are so few favorable conditions for the preservation of the remains of either terrestrial or marine life that if former geological conditions were the same, which is not unlikely, the occurrence of fossiliferous remains may be looked upon as the result of fortunate accidents.

In a preceding chapter it is mentioned that the trilobites are among the oldest known fossils. But it is quite certain that before they fairly had a good start the cephalopods appeared upon the scene to dispute their sovereignty. Among these, the nautilus and the ammonite seem to hold a prominent place. Our present living nautilus is the sole survivor of what in those early times was a very numerous race. More than 2,500 species once swam the Silurian seas, a time in the history of our continent when the waters of the Pacific covered the western half of New York State. The oldest forms have straight shells; but in the course of time coiled shells became conspicuous; later, the race declined, and then they are found sometimes uncoiled

or in baroque contorted shapes. Some were of gigantic size, one species probably weighing several tons, and lengths of five or more feet were not uncommon. Of the ammonites more than 5,000 species are known, but all disappeared from the ocean during the Cretaceous period; that is to say, while the chalk cliffs of England were still beneath the sea. The nautilus race declined more slowly, until to-day we find less than a half dozen species making their last stand in the depths of the tropical Pacific. Contrary to popular belief, they do not swim at the surface, but live near the bottom at a depth of about 1,000 feet—seldom are they found in water of less than 100 feet. To the inexpert eye the shells of ammonites and nautili might easily be mistaken for one another, but there is a difference in the partitions that separate the chambers, and the shells of ammonites are usually more ornamented exteriorly with ridges and projections.

Just about the time the stage was set for the mollusks to appear, however, another creature called the brachiopod, had also established itself. And here, by the way, is something curious. The brachiopod, although not a mollusk, looks, superficially at least, strangely like one. Considering the popular conception of mollusks, I might go further and say that the brachiopod looks more like a mollusk than do many of those animals themselves. There are a few living representatives of this ancient animal, and they are very much like the ancestral type in appearance, being little changed in that long stretch of time since they left their dead shells just off the shores of the Cambrian seas. They live below the low-water mark, usually in depths of 100 feet

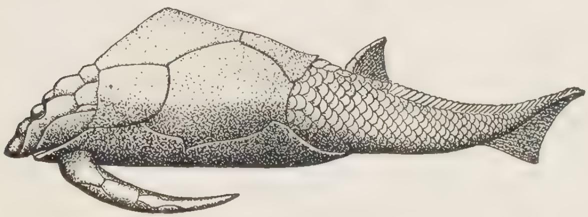
or more, but their heart-shaped shells, generally known as "parchment shells," are often cast up by the waves. They are like the shells of bivalve mollusks, but with this notable difference: the valves in a clam or mussel, for instance, will be found on examination to be not exactly alike in shape; in the brachiopod both valves are similar. There is no need here to go into the internal differences; suffice it to say that in the brachiopod these are so great as to make it more nearly allied to the worms than to the mollusks. When it flourished in its pristine vigor, its numbers became enormous; and it is one of the commonest forms among the oldest fossil-bearing rocks. To-day it is nearly extinct. It would be interesting to know why this comparatively weak and inactive creature has survived throughout that staggering lapse of time, while the sturdy trilobite, whose appearance seems to be contemporaneous, died out these many millions of years ago. But this, like many other secrets of the sea, is too profound even for speculation.

Now, if, as we are led to believe, the evolution of the lower forms preceded in point of time that of the higher forms, we should expect to find evidence of this in the rocks. Well, that is precisely what we do find. It is not until we reach the rocks merging into those which were formed in the period just preceding the creation of the coal beds that we come across the first fish. But this fish is far from looking like any that exists to-day. In general shape it resembles that of a tadpole rather than that of any modern fish. Its comparatively great head is depressed, projects out on the sides, and is attached to a slender body the length of which is not more than twice that of the

head. Its complete outer covering is granular, resembling the rough, rasping hide of the shark. It was, in fact, taken for a form of that animal when first found. The deception was made the more easy on account of its sharklike tail. But when this creature was living, the time of the shark was not yet. In tracing this animal through the next succeeding series of rocks, we find it becomes more fishlike and the rough skin has for the most part given way to tough, horny, and in some cases bony, plates; in short, our creature becomes a mailed fish. Then we find that it becomes very numerous, many families can be recognized, and in some of them the armor has become quite highly specialized. Large overlapping plates invest the head and trunk, and the flexible hind body and tail are covered with hard scales. One dorsal fin was the rule among these armor-bearing fishes, but appended to the sides in the place of the pectoral fins of present-day forms was a pair of ponderous flippers, not unlike those of a sea turtle. Yet all this accouterment did not prevent their extinction, if indeed they may be said to have been exterminated by the attacks of enemies, for they disappeared entirely when the sharks began to dominate the waters of the sea.

The coal age unquestionably saw a remarkable increase in the numbers and in the variations of the forms of animals. This is as true of those that lived on the land as well as those that inhabited the sea. Many old types were dying out, but they were succeeded by others better fitted to cope with the changing conditions of the globe. In point of numbers of individuals, however, the crinoids, corals, brachiopods, and shell-secreting

protozoans far outranked all other forms; and in the various localities in which they thrived, each of these groups built up huge masses of limestone. Here, for the first time in the history of our earth's crust, we find the shell-secreting protozoans (*Foraminifera*) taking a conspicuous place among marine animals. Dense submarine groves of crinoids flourished then as probably they never did before, and their remains to-day are consolidated into deep beds of rock. Sponges grew in the greatest profusion. The brachiopods reached a



PTERICHTHYS; AN ANCIENT FISH.

great size and their shells became exceedingly thick. Hardly less in importance were the mollusks, the univalve and bivalve types in particular growing increasingly abundant. Crustaceans of the higher types now began to assume some prominence, but they were for the greater part represented by the shrimps and prawns. Throughout this period until almost to the very close the sharks were in undisputed possession of their realm.

And then it was that those monstrous reptilian creatures from the land invaded the sea. Like the whales, their structure was modified to suit their aquatic life.

But what forbidding shapes they had! In one remarkable genus, the ichthyosaurians, the body was shaped like that of a fish, the four limbs were developed into paddles, and the tail was long and lizardlike but terminated by a fleshy fin, as in the dolphin, save that it was vertical. The large head was drawn out into a long pointed snout, resembling that of the crocodile, and the jaws were equipped with a series of powerful, conical teeth set close together. The long and slender jaws were strengthened to resist any sudden shock by being composed of numerous thin, bony plates. These plates also made the jaws light and flexible as well as giving them great strength. A feature no less striking was the pair of great eyes contained in the head. In some species these organs were more than a foot in diameter; and they were further remarkable from the fact that they seem to have been fitted to accommodate themselves for vision in air or water as well as for changing their focal distance while the creature was in the pursuit of its prey. The apparatus, which could thus adjust the sight to the needs of the moment, was in principle not unlike that of a diaphragm in front of a camera lens. It consisted of a circle of about twenty overlapping plates surrounding the pupil, and as it was probably capable of closing completely, it must have been of service also in protecting the eyeball during diving. With eyes like these, the ichthyosaurus obviously was at a considerable advantage not only in discovering its prey at great or little distances, but in the obscurity of night and the depths of the sea. The masses of broken bones and scales of contemporary fishes that have been found under the ribs of these creatures make it plain

that they lived almost entirely on those animals. That they were very dangerous enemies of the other larger forms which inhabited the seas with them is evident from their structure; the powerful tail especially must have made them active in their movements, and this together with their predacious habits would tend to make them unusually formidable. The largest known ichthyosaurian had a head measuring about six and one half feet long; when found, the greater part of the body of this animal was missing, but it is probable that the head represents a total length of more than thirty-three feet.

In the same family as the foregoing creatures, and living about the same time, was another genus of sea-dwelling reptiles which left a considerable number of well-preserved remains in the various deposits throughout the world. These were the plesiosaurians. None of them seem to have attained to the length of the ichthyosaurians; but it is certain that they were quite as voracious, if not so formidable. They lived on fishes, cuttlefishes, and other animal prey. The fossilized stomach contents of some of the later types show that they swallowed stones for digestive purposes, just as do the crocodiles of the present day. These strange creatures are considered by some naturalists to be the most singular in structure and in character the most anomalous of any that have been discovered amidst the ruins of former ages. Attached to a slender neck of enormous length was a small head, the jaws of which were filled with sharp gaviallike teeth. The snout was short, but the mouth was capable of gaping very wide. Its tail was somewhat short and apparently not used to

propel the animal; swimming was accomplished by the aid of its four large paddles which grew out from the trunk, and were covered with integument, forming simple undivided flippers, as in the turtle. Although nothing is known of its general habits, speculation has not been wanting; and it has been presumed that it swam on or near the surface, occasionally snapping up any prey which happened to come within the compass of its long snakelike neck; or that it may have lurked in the shallow water along the shore, concealed among the seaweeds, raising its nostrils to the surface from time to time for breath. Both the ichthyosaurus and the plesiosaurus and all their brethren that took to the sea had perished from the earth before the British Isles were raised from their oceanic crib.

From the time of the first trilobites, the Cambrian age, to the era that was marked by the formation of those isles, that is, the age of chalk, the lapse is so overwhelmingly vast that there is absolutely no comparative measure by which it can properly be appreciated. The mind fails utterly in any attempt to conceive in their relative light the stupendous number of years that it must have taken to bring about what appear to be some of the most transient conditions in the history of the earth. Some day man may be able to determine quite accurately, in round numbers at least, the age of organic life on this globe; but, when all is said, the figures will be meaningless to the imagination. In truth, there is not anything within the province of language that can adequately convey a conception of that awful span which bridges the dawn of life with the chalk period.

And how tremendously removed from the present

must be even that period! We think the pyramids are old. But observe; the stones with which they are built are obviously ages and ages older. They are composed of shells that had fallen to the bottom of an ancient sea; the compacted masses hardened and were lifted above the surface forming part of a great continent. Yet as old as must have been the nummulites which formed that stone, there is strong evidence that when the saurians swam the seas, this species of protozoan was not yet in existence.

Chapter XIX

OUR SALT-WATER WORLD

Every schoolboy knows, as Macaulay would say, that the ocean is one continuous sheet of water covering more than three fifths of the whole surface of the earth. And although no part of it is separated from the rest, the intervening land areas mark it off in five great divisions known as the Atlantic, Pacific, Indian, Arctic, and Antarctic oceans. But of the general characters and conditions of the sea, none of us is too highly aware. So our final inquiry will be directed not so much toward the geographical aspects of that great realm whose inhabitants have occupied the major portion of this work, but rather toward some of the physical and closely related aspects of the element in which they live.

Oceanography, or the science of the sea, is a comparatively recent development. When scientific investigation of the sea began we were obliged to get most of our information from conditions prevailing near the shore or from mariners whose reports of conditions far from land were generally colored with marvelous or frightful accounts. But with the later rapid increase in the study of the exact sciences came the development and invention of accurate instruments; and with the aid of these, observations are now easy and common. Even

the ship's logs of to-day have special headings under which are listed the various phenomena as they occur on the surface. But undoubtedly the greatest advances in oceanography were occasioned by the researches of those expeditions made in vessels especially equipped for the purposes of exploration and investigation. Obviously, these are costly affairs and are not often undertaken; but limited as have been these enterprises, their achievements have been remarkable. Various governments and private individuals have by means of these expeditions done much to further our knowledge of the open sea; however, the most noteworthy expedition may be said to be that of the *Challenger*, which was really the scientific pioneer of the seas. This vessel, under the English flag, made a voyage starting in December 7, 1872, and lasting until May 24, 1876. In this period of three and one half years she several times crossed and recrossed various seas; having covered in the entire length of the cruise nearly 69,000 nautical miles. From the time of this epoch-marking event dates the beginning of oceanography as a science of precision.

Not only is the area of the sea larger than that of the land, but its volume is also greater. If the entire exposed portion of the earth were dumped into the ocean, it would not take up more than one fourth of the space occupied by the water; in short, it would be covered by an ocean 8,700 feet in depth. The mean elevation of the land above the sea level over the whole world is less than half a mile; this is to say that if all the mountains and high portions of land could be made to fill the low parts the leveled earth would rise above the sea

almost exactly 2,300 feet. The sea, on the other hand, has a mean depth of more than two miles. Nine tenths of it is more than a mile deep, and two thirds of its depth is more than two miles.

The ocean basin, on the whole, is very smooth and stretches out in great level plains. All the greatest depths seem to occur in trenches, rather than in gradually sloping valleys. Most of them are narrow, but are quite long, and their steeper side is supposed to be the result of a fracture in the crust of the earth. This is indicated by the fact that deeps are more often associated with regions of frequent submarine earthquakes. But the great deeps, those of excessive depths, are not nearly so extensive as is commonly imagined; the total area where the depth is more than three miles is probably not more than one one hundred and forty-fifth of that of the sea floor. Life has been found in all of them, but at those depths any object is under a pressure of five tons to the square inch.

It is in the Atlantic Ocean that the newer and trustworthy methods of sounding have chiefly been employed, and the contours of its floor may now be considered as fairly well known. The greatest depth is in the Virgin Islands Deep, which was measured by the *Challenger,* and it lacks 510 feet of being four and a half miles deep. But over the greater part of the Atlantic basin, the depth ranges between two and one-half and three and one-half miles. Along the middle, in a north-and-south direction, runs a great irregular ridge on which the depth is less than two miles, and a plateau of about the same depth extends almost continuously from Newfoundland to the British Isles. It

was the discovery of this plateau that facilitated the laying of the telegraph cables, and it is known in the charts as Telegraph Plateau. As this elevated plain approaches the British Isles, the water becomes comparatively shallow; nowhere in that vicinity is the depth more than 400 feet.

From the numerous islands that dot the Pacific Ocean, one would be inclined to believe the waters in their region to be somewhat shallow; but this is far from what is actually the case. The fact is that the islands rise abruptly from very great depths, and some of them are close to the deepest soundings that have yet been made. In another chapter I have mentioned the Philippine Deep as the deepest part of the ocean, but there is another deep spot almost in the same region which was famed for years as the greatest depression in the earth's crust; this is the Tuscarora Deep, off the coast of Japan, with a depth of slightly more than five and one-fifth miles.

So far as soundings have been able to determine, the Indian Ocean contains no such deeps as have either the Atlantic or Pacific, but there are vast expanses of its floor forming an almost level plain at a depth of three or more miles. The deepest known region is the Sunda Trench, south of Java, where a sounding of nearly four and one-third miles was made.

Of the Arctic and Antarctic oceans, the latter is conceded to be the deeper, although comparatively little is known about either of them. North of Siberia, the bed of the Arctic has a remarkably gentle slope, the water in that region being less than 100 feet in depth at a distance of one hundred and fifty miles from the

shore. From this it is generally concluded to be by far the shallowest of all oceans.

The deep transparent blue of the ocean has been celebrated in the literature of every age. In just what way the sea assumes its remarkable color does not seem to be well understood. That the depth of the water is in some manner associated with this phenomenon would appear from the fact that the purest blues are mostly far from land, whereas, it is well known, the shallows of the tropics are always green. On the other hand, it may be pointed out that the Rhone, at its emergence from Lake Geneva, and indeed the lake itself, exhibits an intensity of blue which surpasses that of any sea. Then, there is also no doubt but that a distinct relationship exists between the color of the water and its purity, or transparency. Water that contains fewer small floating organisms is more blue than is otherwise the case. An increase in the turbidity is generally accompanied by an increasing cast of green. The transparency of sea water has often been measured in different parts of the globe, and it was found that great differences exist between various regions. In the Sargasso Sea a white disk six feet in diameter could be observed 216 feet below the surface; the same disk in the equatorial currents and the cold currents of the north was visible only in about half that depth. The purest oceanic blues are found in the warm regions of the Pacific and the Indian oceans and in the Sargasso Sea of the Atlantic. The optical property of sea water is of considerable biological importance, as it affects the penetration of sunlight and its consequent influence on the growth of vegetation. Every plant, of course,

needs light to reduce the carbonic acid required for its existence. Some require more, and others may want less; without it, however, no vegetation can live. The actual depth to which light penetrates obviously would vary in different localities, but generally speaking it may be said that at depths of 600 feet no light can be received from the sun, and even at depths considerably less the amount that filters through is so feeble as to have little or no influence on life.

Every year approximately 475,000,000 tons of salts and other chemicals dissolved from the land are carried into the ocean by the rivers of North America alone. There exists at present in solution in the sea, 4,800,000 cubic miles of salts; this quantity is more than enough to cover the surface of the United States one and one-half miles deep. Of the eighty odd known elements, thirty-two have been proved to exist in sea water; and it is quite probable that as the analytical methods of chemistry become more refined, the presence of nearly all the rest will be revealed. Seaweeds and corals contain many of the metals, but gold and silver have actually been found in solution. It has been estimated that nearly one fifth of a grain of silver is contained in a ton of sea water; there is, then, dissolved in the sea nearly fifty thousand times as much of this precious metal as has been mined throughout the world since the discovery of America. But this is insignificant as compared with the quantity of gold it is presumed to contain. Gold is estimated to be five times as plentiful as silver in the sea. Needless to say, man has constantly and unsuccessfully attempted to extract the gold from the water.

Of all the elements, sodium chloride, or common salt, exists in the largest amount; this being present in the proportion of 27.213 per 1,000 parts of water. Other salts exist also, though in minor quantities; still they are sufficiently voluminous to impart a distinctly bitter taste; and they, together with the sodium chloride, make the water unsuitable for drinking or domestic purposes.

The specific gravity of sea water is correlated with its salinity, or saltiness. This is merely to say that salt water is more buoyant than is fresh water; objects will not sink so readily in the sea as they will in fresh water. But the comparatively greater buoyancy of the sea is not so marked as is generally believed. It is so slight, in fact, as to be ordinarily imperceptible; assuredly, the difference is not great enough to be detected by the bather, as has been frequently maintained. The specific gravity of pure fresh water at a temperature of 39.2° Fahr. is 1, the standard unit to which the specific gravities of all liquids and solids are referred. The specific gravity of the sea, out of reach of such exceptional influences as those of the melting snow, rain, or river water, is 1.02655 at a temperature of 62° Fahr. Slight variations in the saltness of the ocean occur in different localities, and these necessarily produce corresponding changes in its specific gravity. On the north and south limits of the torrid zone the mean specific gravity appears to be less than that of the equatorial calm belt; and it shows a tendency to diminish as the latitude increases.

Where the sea is not affected by currents from warmer or colder regions, its temperature corresponds

with that of the normal temperature of the latitude. However, this is true only of the surface water. It has been shown that the temperature diminishes very rapidly with the depth, in tropical and temperate latitudes particularly, till at great depths the ice-cold temperature of 35° Fahr. everywhere prevails. At the equator, where the surface temperature is about 80°, the decrease with the depth is so rapid that at 360 feet from the top the temperature is less than 61°; at 190 feet it falls to 50°; at 4,200 feet it again falls to 40°; and at a little more than one and three-fourth miles it is 36°. Below this depth it falls at a much slower rate, till in some regions it approaches very close to freezing temperature, which, for sea water, is about 28.6°. In the equatorial belt the solar heat affects the water of the upper four hundred feet; but it is a remarkable fact that immediately beneath this sun-heated stratum the water in the North Atlantic as far as the fortieth latitude is warmer than that at the same depth at the equator.

In a peculiar sense the ocean has its rivers and lakes as well as the land, its mighty currents and areas of distinct specialization. The rivers cross and recross, they diverge and come together, and in many cases they do so without mingling their waters to any great extent. The lakes, or little seas, are no less distinctive in their characteristics. They are not distinguished by the character of their currents or margins, however, but by the floating vegetation they contain.

The nearest of these tracts to our shores is the Sargasso Sea in the Atlantic, between Bermuda and the

Virgin Isles. It consists largely of great drifting fields of the fucoid seaweed Sargassum, commonly called the gulfweed. It is the same plant which composes similar "seas" in the Pacific and Indian oceans. Although its quantities are enormous, and although it has never been found otherwise than while floating, there is reason to think that this seaweed grows originally on the bottom of comparatively shallow parts of the sea. Its presence in the north Atlantic is regarded by voyagers as a certain indication of the Gulf Stream, by which it is carried northward and eastward.

Of all the great oceanic rivers, the Gulf Stream is the most important and the most widely known. Starting in the Gulf of Mexico, from which it derives its name, it flows between the coast of Florida on one side, and Cuba and the Bahamas on the other, and passes northeast along the American coast until it reaches the island and Banks of Newfoundland, when it veers across the Atlantic and divides into two divergent parts, one of which swings east toward the Azores and the coast of Morocco, while the other washes the shores of the British Isles and Norway, and continues in its onward course past the southern coasts of Iceland and Spitzbergen, finally losing itself in the Barents Sea and the Arctic Ocean. As it leaves the Florida Straits, which is its narrowest portion, it is fifty miles wide; here with a velocity of three and one-third miles an hour it sweeps along majestically like an immense torrent. As it proceeds its speed diminishes and its current gradually grows wider. By the time it has passed the Newfoundland Banks its width has expanded for hundreds of miles.

The waters of the Gulf Stream are of a deep sapphire blue, and they show a sharp contrast to the light green of the seas through which they pass in their early course. As this mighty river leaves the Gulf of Mexico, it has a temperature of 84° in summer, which is four degrees higher than obtains in the ocean at the equator. Even in mid-Atlantic, off Nova Scotia, its temperature at no season falls more than 15°; while the northwestern coasts of Europe are laved by its warm waters, waters which were heated more than 1,400 miles away under a tropical sun. As a result their winter temperatures are raised about 30° above the normal temperatures of the latitudes. To its beneficent and genial warmth, England owes its humid climate, and Ireland its perennial green. Scotland, graced with verdure throughout eleven months of the year, is in the same latitude as is the bleak and frozen coast of Labrador. And even Lisbon, though in the mild region of the Mediterranean, is not unaffected by the flow of its southward course. Here, too, a parallel may be drawn. In the same latitude Washington is subject to blizzards, and the Potomac sometimes freezes in a single night; Lisbon scarcely knows a frost.

For the cause or causes of the Gulf Stream, we must turn to the trade winds. These winds prevail along the equatorial belt, and blow steadily all year from east to west. Their strength and impetuosity may vary, but they are always in evidence. They encircle the globe, and are the primary cause of every other great oceanic current. Westward in the Atlantic Ocean, their continuous action sets up a flow of water just north of the equator; and this water, encouraged by these winds,

starts slowly toward the northeast coast of South America where it is deflected into the Caribbean Sea, flowing thence between Yucatan and Cuba into the Gulf of Mexico. The Gulf acts as a great reservoir, and the waters thus wafted into it raise its surface several feet above the level of the Atlantic. As there are but two straits connecting the Gulf of Mexico with the outside ocean—the Yucatan channel through which the trades are continuously forcing more water, and the passage between Florida and Cuba—the Gulf is obliged perforce to discharge its pent-up waters through the opening that offers the least resistance. Therefore, it pours out its mighty volume through the narrow passage in the east, where they round the Florida keys and turn to the north. Until the Gulf Stream passes Cape Hatteras, North Carolina, it clings to our coast rather closely; beyond that point it stretches out into the cold waters of the north. As a result the seaboard below the cape is not exposed to any cold currents, and the temperature of the adjacent region is modified from the heat of the Gulf Stream. The shores to the north of the cape, on the contrary, are exposed to a great current from the Polar Seas, which runs inside and counter to the Gulf Stream, and comes freighted with ice from the northern latitudes. In midwinter, off the inclement coasts of our continent, between Cape Hatteras and Newfoundland, ships beaten back from their harbors by fierce northwesters, buffeted and loaded down with ice and in danger of foundering, turn their prows to the east, and find relief and comfort on the bosom of the Gulf Stream.

Although the Pacific Ocean has its great equatorial

or trade-wind current, it has no great basin like the Gulf of Mexico to store the waters of another Gulf Stream; no other ocean but the Atlantic contains a current of such energy and volume. And no other current affects so large a part of the surface of the earth. At first sight it seems incredible that a current of water should force itself through the ocean with distinct boundaries and with a different color, temperature, and even inhabitants (for the creatures which live in its tropical warmth seldom stray into the colder seas), like a mighty river between its banks, flowing for thousands of miles against counter-currents which sometimes actually cross its course, passing under by their greater density, until it loses its momentum on the shores of far-off continents or spreads out in the distant north to temper the frigid seas. But all this, as closer observation will soon convince us, is in accordance with the physical laws of fluids. It is well known that great inland streams, such as, for instance, the clear waters of the Mississippi and the turbid currents of the Missouri, do not unite at once at their confluence, but continue side by side for many miles before they mingle. And all great rivers running into the ocean are rivers still, far out at sea. The Rio de la Plata, which drains the southern part of South America, continues to flow after it leaves the land, and can be perceived in its course two hundred miles from the shore. The Amazon runs far into the Atlantic, though it is there gradually bent to the north by the trade-wind currents, and helps, with the waters of the Orinoco, to swell the Gulf of Mexico. From this it will be seen that the Mississippi, the Rio Grande, the Ori-

noco, and the Amazon all contribute to the waters of the Gulf Stream.

Such, in brief, is the nature and capacity of the Gulf Stream—preëminently the most potent factor for the progress of civilized man. Without its influence, the greater part of cultured Europe would be a cold and cheerless waste, uninhabited save by such rude races as the Eskimos and Lapps. Over a large part of our own salubrious land would descend long and dreary winters, and desolation would prevail throughout what are at present the fairest and loveliest portions of the earth.

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